APPENDICES

Contra Costa County General Plan 1990-2005

Draft

October 1990

APPENDICES

TO THE

CONTRA COSTA COUNTY GENERAL PLAN

CONTRA COSTA COUNTY

October 1990

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HOUSING MARKET ANALYSIS

APPENDIX A

HOUSING MARKET ANALYSIS

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I. Population Growth

Historic Growth

Prior to 1940, the County's population was concentrated along the County's shoreline. During World War II, West County, in particular Richmond and its surrounding communities, grew rapidly to house the work force for war-related shipbuilding and other industries. Construction of the Caldecott Tunnel in 1937 between Berkeley and Orinda opened up Central Contra Costa County as a series of bedroom communities serving the employment centers of Oakland and San Francisco. Several decades later, further suburban expansion was spurred by construction of the BART rail line between San Francisco, Oakland and Concord.

The County experienced the most rapid growth in the decade between 1940 and 1950, as rapid growth occurred in Richmond and in Central County and almost 200,000 residents were added to the County, a doubling of the population (see Table 1). Contra Costa grew by more than one third during both of the following decades, registering growth rates between 1950 and 1960 and between 1960 and 1970 of 36.8% and 35.9%, respectively.

Table 1
Historic and Projected Populations and Population Growth: 1900-2000

Year	Population	Percentage Change
1900	18,046	
1910	31,674	75.5%
1920	53,889	70.1
1930	78,608	45.9
1940	100,450	27.8
1950	298,984	197.6
1960	409,030	36.8
1970	555,805	35.9
1980	656,380	18.1
1990	803,553	22.3
2000	943,000	18.7

Source: 1900-1980 U.S. Bureau of the Census as of April 1;
1990 California State Department of Finance, Demographic Research Unit, January 1, 1990;
2000 ABAG, Projections 90

By the time of the 1980 U.S. Census, the population of Contra Costa County had jumped to 656,380, representing an increase of 100,000 more residents during the decade of the 1970s. or a growth rate of 18.1%.

Contrary to some common perceptions, Contra Costa County has not been one of the fastest growing areas in California during the most recent period of 1980 through July 1989. The County's growth rate of 20.4% during that period compared to an overall growth rate in the nine county San Francisco Bay Area of 14.3%. However, during the same period, the entire State grew at a rate of 22.8%, led by rapid population growth in Southern California.

Table 2 shows the population growth that has occurred in the individual cities of Contra Costa County since 1900. During the decade of the 1970s, the most rapid growth rates were experienced by the cities in West County in Hercules (2266.0%), in East County in Brentwood (67.4%), Pittsburg (60.0%), and Antioch (52.1%), and in Central County in the City of Clayton (135.7%). The cities with the most rapid growth rates between 1980 and 1990 were Hercules (183.3%), Clayton (59.6%), and Brentwood (59.2%). Much of the growth in Clayton and Brentwood was due to annexations. The cities which have experienced the greatest absolute population growth between 1980 and 1990 are: Antioch (an additional 19,349 residents), Pittsburg (12,629), Walnut Creek (10,225), Hercules (10,929), Martinez (8,417) and Richmond (9,668).

Some unincorporated communities that are not listed individually in Table 2 have also grown very rapidly. Both Danville (incorporated in 1982) and San Ramon (incorporated in 1983) have experienced substantial growth since the mid-1970s, as have the Oakley, West Pittsburg, and Discovery Bay unincorporated areas.

The portion of the County population that lives in unincorporated areas has declined as cities have annexed land into their jurisdictions and new cities have incorporated. The population in the unincorporated county has fallen from roughly one half of the total population in 1960 to almost 30% in 1980 and to 19% in 1990 (see Table 3).

TABLE 2

CITY AND COUNTY GROWTH
1900-1990

Jurisdiction	Date of Incorporation/Formation	1900	1910	1920	1930	1940	1950	1960	1970	1980	1990
Antioch	February 2, 1872	694	1,124	1,936	3,563	5,106	11,051	17,305	28,060	42,683	62,032
Brentwood	January 1, 1948	-----	-----	-----	-----	-----	1,729	2,186	2,649	4,434	7,060
Clayton	March 18, 1964	-----	-----	-----	-----	-----	-----	530	1,835	4,325	6,901
Concord	February 2, 1905	-----	703	912	1,125	1,373	6,963	36,208	85,164	103,255	111,332
Danville[3]	July 1, 1982	-----	-----	-----	-----	-----	-----	-----	-----	-----	31,601
El Cerrito	August 20, 1917	-----	-----	1,505	3,870	6,137	18,011	25,437	25,190	22,731	23,374
Hercules	December 15, 1900	-----	279	373	392	343	343	310	252	5,963	16,892
Lafayette[1]	July 22, 1968	-----	-----	-----	-----	-----	-----	16,550	20,484	20,879	23,305
Martinez	April 1, 1876	1,380	2,115	3,858	6,569	7,381	8,268	9,604	16,506	22,582	30,999
Moraga[2]	November 13, 1974	-----	-----	-----	-----	-----	-----	-----	11,327	15,014	16,373
Orinda[3]	July 1, 1985	-----	-----	-----	-----	-----	-----	-----	-----	-----	17,751
Pinole	June 25, 1903	-----	798	967	781	834	1,147	6,064	13,266	14,253	16,949
Pittsburg	June 22, 1903	-----	2,372	4,715	9,610	9,520	12,763	19,062	20,651	33,034	45,663
Pleasant Hill[1]	November 14, 1961	-----	-----	-----	-----	-----	-----	19,170	24,610	25,124	32,296
Richmond	August 7, 1905	-----	-----	16,843	20,093	23,642	99,545	71,854	79,043	74,676	84,344
San Pablo	April 26, 1948	-----	-----	-----	-----	-----	14,476	19,687	21,461	19,750	21,612
San Ramon[3]	July 1, 1983	-----	-----	-----	-----	-----	-----	-----	-----	-----	35,966
Walnut Creek	October 19, 1914	-----	-----	538	1,014	1,578	2,420	9,903	39,844	53,643	63,868
Incorporated		2,054	14,193	31,647	47,017	56,014	176,706	217,620	378,565	462,346	688,318
Unincorporated		15,992	17,481	22,242	31,591	44,436	122,276	191,410	177,240	194,034	154,615
Total County	February 18, 1850	18,046	31,674	53,889	78,608	100,450	298,984	409,030	555,805	656,380	835,553
Change from Previous Decade		-----	13,628	22,215	24,719	21,842	198,534	110,046	146,775	100,575	160,551
% Change			75.5	70.1	45.9	27.8	197.6	36.8	35.9	18.1	19.2

[1] In 1960, Clayton, Lafayette and Pleasant Hill were unincorporated.
[2] In 1970, Moraga was unincorporated.
[3] In 1980, Danville, San Ramon, and Orinda were unincorporated.
[4] Estimated by California State Department of Finance, for January 1, 1990

Source: U.S. Bureau of the Census, California Department of Finance, Contra Costa County Community Development

Table 3
Population Distribution Between County Incorporated and Unincorporated Areas (1900 - 1990)

	Incorporated		Unincorporated	
	Number	Percent	Number	Percent
1900	2,054	11.4	15,992	88.6
1910	14,193	44.8	17,481	55.2
1920	31,647	58.7	22,242	41.3
1930	47,017	59.8	31,591	40.2
1940	56,014	55.8	44,436	44.2
1950	176,706	59.1	122,276	40.9
1960	217,620	53.2	191,410	46.8
1970	378,565	68.1	177,240	31.9
1980	462,346	70.4	194,034	29.6
1990	648,318	80.8	154,615	19.2

Source: U. S. Bureau of the Census, California Department of Finance, Contra Costa County Community Development Department

The largest amount of land transferred out of County jurisdiction has been the result of three incorporations during the 1980s: the Town of Danville (incorporated in 1982), the City of San Ramon (1983), and the Town of Orinda, which officially became a city in July, 1985. Major annexations of unincorporated lands have occurred during the last ten years in the San Ramon Valley; in the Castro Ranch Road area of Richmond and in Hercules; in Lafayette, Walnut Creek, and Clayton; and in the growing southeast area of Antioch and the lands west of Brentwood. Most recently, large areas have been added to the cities of Danville and San Ramon, as the Bishop Ranch Business Park, the Canyon Lakes project and several other Tassajara subdivisions have been completed and immediately annexed. From a high of almost 195,000 residents living outside city boundaries in 1968 (just prior to the incorporation of Lafayette), the unincorporated population in the County has declined to 154,615 in 1990.

Of the three sub-areas of the County, Central County experienced the most rapid growth during the 1960s at a 63.1% growth rate, compared to 10.8% and 26.2% in West and East County, respectively (See Table 4). During the 1970s, East County experienced the greatest growth rate of 45.0%, compared to a decline in West County of 2.4% and a growth rate of 24.3% in Central County. From 1980 to 1990, East County has continued to grow more rapidly than the other areas of the County with a 47.8% growth rate, versus 15.4% in West County and 18.0% in the Central area.

Table 4
Population Growth in
Contra Costa County by Sub-Area
(1960-1990)

	1960	1960-70 % Change	1970	1970-80 % Change	1980	1980-90 % Change	1990
West County	170,163	10.8%	188,602	-2.4%	184,151	15.4%	212,600
Central County	178,315	63.1%	290,779	24.3%	361,392	18.0%	426,500
East County	60,552	26.2%	76,424	45.0%	110,837	47.8%	163,900
Total County	409,030	35.9%	555,805	18.1%	656,380	22.3%	835,553

Source: 1960, 1970 and 1980 U.S. Bureau of the Census; California Department of Finance; Contra Costa County Community Development Department as of January 1990.

Note: West County includes the cities of El Cerrito, Richmond, San Pablo, Pinole, and Hercules; Central County includes Martinez, Pleasant Hill, Concord, Clayton, Walnut Creek, Lafayette, Moraga, Orinda, Danville, and San Ramon; East County includes Pittsburg, Antioch, and Brentwood.

Population Distribution

Over half of the population in the County lives in Central Contra Costa County, while 20.4% of the County residents live in East County and 26.5% live in West County (see Table 5). Currently, 19.3% of the County's population lives in an unincorporated area while 80.7% live in one of the eighteen cities in Contra Costa.

Table 5
Distribution of Population By Sub-Area
Number and Percent
(1970-1990)

	1970	1980	1990
West County	188,602 (33.9%)	184,151 (28.1%)	212,600 (26.5%)
Central County	290,779 (52.3%)	361,837 (55.1%)	426,500 (53.1%)
East County	76,424 (13.8%)	110,837 (16.9%)	163,900 (20.4%)
Total	555,805	656,380	835,553

Source: U.S. Bureau of the Census, 1970 and 1980; California Department of Finance and Contra Costa County Community Development Department

During the last two decades, the proportion of the County in the West County area has declined from 33.9% to 26.5% of the County's population, while Central County has remained somewhat stable, at slightly over half of the County's population and East County has increased its share from 13.8% to 20.4%.

Population Projections

ABAG projects that Contra Costa County will increase in population by 9% between 1990 and 1995 (see Table 6). The "Other East" area is anticipated to have the most rapid growth rate of 27.3%, with the Pittsburg-Antioch area following with 18.8% growth. Lamorinda is expected to have the slowest growth with 1.9%.

Table 6
Population Projections by Sub-Areas of the County

	1990	1995	Number and % Change	
West County	207,700	214,700	7,000	3.4%
North Central	271,900	285,600	13,700	5.0
Lamorinda	57,100	58,200	1,100	1.9
San Ramon Valley	92,325	108,100	15,775	17.1
Pittsburg-Antioch	123,100	146,200	23,100	18.8
Other East	37,875	48,200	10,325	27.3
Total	790,000	861,000	71,000	9.0

Source: Association of Bay Area Governments, Projections 90; Contra Costa County Community Development Department. 1990 figures are ABAG estimates

II. Household Growth

Historic Household Growth

While population is often used as the single measurement of growth, household growth is a more important indicator of housing demand. One of the most striking and well documented changes in the demography of the Bay Area, California, and the nation during the decade of the 1970's was the decrease in average household size. Following state and national trends, the average household size in the nine county San Francisco Bay region decreased from 2.9 persons to 2.57 persons during the 1970's, while the average in Contra Costa County plummeted from almost 3.2 persons per household to less than 2.7 ten years later. The County's household size has continued to decrease in the 1980's although not as drastically as in the previous decade.

The major factors contributing to the decline in household size over the last two decades were the large number of young individuals entering the labor force who set up their own households, and the increase in the number of households headed by individuals over the age of 65. Declining household size also reflected the changing structure of the family, increasing divorce rates, delayed marriage and child bearing ages, and smaller family sizes.

Average household sizes are also a function of the availability of affordable housing and the type of new development occurring in the area. Households tend to double up, young adults tend to leave home to establish separate households later, and seniors are more likely to live in extended families, if affordable

housing is not available. During periods of declining affordability (in terms of rents and sales prices exceeding increases in incomes) household sizes would tend to increase. Average household sizes in a particular area would also change if average unit sizes of new development shifted. The shift in Contra Costa County away from single family development, as multi-family has increased from 17.7% in 1980 to almost 46.3% of new development in 1988, has an impact on declining household sizes as smaller, more affordable units are available.

Because of the decreasing household size, the creation of new households and the demand for new housing units in Contra Costa County has exceeded the porportional increase in population since 1970. Table 7 illustrates this point. Between 1970 and 1980, the County's population grew by 18.1%, while households grew more than twice as fast (almost 40%) and the housing stock increased by 41.8%. (The difference between the number of households and housing units is related to the vacancy rate, i.e. the number of unoccupied housing units.) Since 1980, the household and population growth rate has been much closer. While the County's population increased 22.3% between 1980 and 1990, the number of new households that were formed rose by 26.2% and the number of new housing units increased by 25.2%.

Table 7
Increase in Contra Costa County Households, Housing Units and Population (1970 - 1990)

	1970-1980		1980-1990	
	Increase	% Change	Increase	% Change
Households	68,583	39.7%	63,206	26.2
Housing Units	74,296	41.8	62,942	25.3
Population	100,575	18.1	146,553	22.3

Sources: U.S. Department of Commerce, 1970 and 1980 Censuses of Population; California Department of Finance population and household estimates for January, 1990; Contra Costa County Community Development Department.

Household Projections

ABAG estimates that the number of Contra Costa County households will grow by 30,700 between 1990 and 1995, at a growth rate of 10.1% (see Table 8). This exceeds slightly the projected population growth rate of 9.0% for the same time period. The most rapid growth is expected in East County, followed by San Ramon Valley. West County is expected to add 4,100 new households, Central County 13,007, and East County 13,593 new households. Assuming a vacancy rate of 5%, 32,235 new housing units would be needed to accommodate the anticipated 30,700 households.

Table 8
Household Projections by Sub-Areas of the County

	1990	1995	Number and % Change	
West County	80,930	85,030	4,100	5.1
North Central	111,580	117,740	6,160	5.5
Lamorinda	21,320	22,210	890	4.2
San Ramon Valley	31,508	37,465	5,957	18.9
Pittsburg-Antioch	44,710	54,110	9,400	21.0
Other East	13,642	17,835	4,193	30.7
TOTAL	307,450	334,390	30,700	10.1

Source: Association of Bay Area Governments, Projections 90; Contra Costa County Community Development Department

III. Labor Force and Employment Growth

Labor Force Growth and Characteristics

The number of Contra Costa County residents who contributed to the Bay Area labor force increased substantially in the two decades between 1960 and 1980 (Table 9). As of January, 1990, Contra Costa County residents made up 12.7% of the civilian labor force in the 9 Bay Area Counties.

During the decade of the 1960's, the growth rate in the labor force outstripped both the rate of new jobs created in the County and the increase in population (see Table 10). Between 1960 and 1970 approximately 39,000 jobs were created in the County, while the growth in resident workers was almost double that number (74,000), while the population increased by 146,000 new residents.

The following decade of the 1970's again saw an increase in workers which far outweighed the growth in jobs in the County. Coincidentally, the increase of 100,000 new workers in the County between 1970 and 1980 almost exactly matched population growth during that period. However, only 71,300 new job positions were created by local employers during the decade, resulting in many residents commuting out of the County. Likewise, between 1960 and 1970, job creation in Contra Costa amounted to only one-half of the demand for employment by new workers, adding to the already prevalent out-commute pattern.

Table 9
TOTAL COUNTY LABOR FORCE 1960-1990

	Number	% Change
1960	152,313	
1970	226,375	48.6
1980	326,530	44.2
1990*	422,300	29.3

Source: U.S. Bureau of the Census; *State of California, Employment Development Department, January, 1990.

Table 10
Increases in Contra Costa County Jobs, Labor Force and Population (1960-1990)

	1960-1970 Increase	% Change	1970-1980 Increase	% Change	1980-1990 Increase	% Change
Jobs	39,200	44%	71,300	56%	91,463	45.5%
Labor Force	74,062	48.6	100,155	44.2	95,770	29.3
Males	39,684	37	40,554	27	--	--
Females	34,378	79	59,601	77	—	—
Population	146,775	35.9	100,575	18.1	146,553	22.3

Source: U.S. Department of Commerce, 1960, 1970, and 1980 Censuses of Population, Tables P-1 or 14, and 176; job, labor force and population, California Employment Development Dept., estimate for January 1990.

A major factor during the 1970's which contributed to the decade's 44% growth rate in the number of jobs was the entrance of almost 60,000 women into the labor force. The phenomenon of much higher labor force participation rates for females was caused in part by the increasing need for many households to rely on two incomes to meet rising housing costs.

During the most recent period of 1980-1990, the relationship between the growth of new jobs and new workers in Contra Costa County has become more comparable. Due to the boom in commercial construction in Central County, the County's employment base has expanded by over 91,400, while 95,790 new workers have entered the labor force. During the same period, over 146,553 new residents have moved into Contra Costa.

The rate of job growth over the ten year period has been very high, over 45%, which was more than 50% greater than the rate of expansion in the number of labor force participants (a 29% increase). This changed the trend of the two previous decades, when the number of new employment opportunities fell far below the number of new residents who became a part of the labor force. The employment growth rate has remained at least double that of the population growth rate.

The number of females in the labor force, although fewer than the number of males, increased at a faster rate than male workers. The percentage of the work force consisting of women increased from 29% in 1960 to 42% in 1980, with an estimated increase to 43.8% in 1990 (see Table 13). The male labor force experienced a 73.7% growth between 1960 and 1980, while the female labor force increased by 215.7%.

Table 11
Labor Force By Age and Sex 1960-1990
Number in Labor Force

	1960		1970		1980		1990	
Age	Male	Female	Male	Female	Male	Female	Male	Female
16-19	5,225	3,074	9,975	6,081	12,833	11,818	11,300	13,100
20-24	7,758	4,110	14,800	10,543	22,450	18,508	22,900	22,600
25-34	24,977	8,324	33,145	15,524	51,059	39,446	64,000	51,400
35-44	31,918	13,529	33,678	17,431	42,036	30,255	59,000	45,400
45-64	36,085	13,607	53,608	26,666	56,169	35,296	74,100	49,200
65+	2,785	921	3,226	1,697	4,439	2,221	5,800	3,000
Total	108,748	43,565	148,432	77,943	188,986	137,544	237,100	184,700

Source: U.S. Bureau of the Census, 1960, 1970, 1980; ABAG Projections 90 estimate for 1990. Projected 1990 figures are for age 15-19, rather than ages 16-19. ABAG breakdown for male and female labor force participation is for civilian labor force only. Compared to Census data, which include military employees. For 1980 labor force participation by sex, ABAG data was 1% lower for the percent males in the labor force.

Table 12
Labor Force By Age and Sex 1960-1990
Percentage of Labor Force

	1960		1970		1980		1990	
Age	Male	Female	Male	Female	Male	Female	Male	Female
16-19	63.0%	37.0%	62.1%	37.9%	52.1%	47.9%	46.3%	53.7%
20-24	65.4	34.6	58.4	41.6	54.8	45.2	50.3	49.7
25-34	76.4	23.6	68.1	31.9	56.4	43.6	55.5	44.5
35-44	70.2	29.8	65.9	34.1	58.1	41.9	56.5	43.5
45-64	72.6	27.4	66.8	33.2	61.4	38.6	60.1	39.9
65+	75.1	24.9	65.5	34.5	66.7	33.3	65.9	34.1
Total	71.0%	29.0%	66.0%	34.0%	58.0%	42.0%	56.2	43.8

Source: U.S. Bureau of the Census; ABAG, Projections 90 estimates for 1990.

Table 13
Percent Increase in Labor Force By Sex - 1960's & 1990's

	1960-1970	1970-1980	1980-90	1960-90
Labor Force	48.6%	44.2%	28.8%	177.3%
Male	36.5	27.3	25.5	118.0%
Female	78.9	76.5	34.3	323.9%

Source: U.S. Bureau of the Census; ABAG Projections 90 estimates for 1990.

Table 14
Labor Force Participation Rate
1980-1990

	1980	1990	1995
Male	74.2%	77.0%	77.2%
Female	52.0	56.9	60.1
Total	62.7	66.7	68.4

Source: ABAG, Projections 90. 1990 and 1995 are projections.

Labor force participation rates, or the percent of the labor force which is employed, are expected to increase for both males and females (see Table 14). However, ABAG projects that male participation rates will increase by 4%, while female participation rates are projected to increase by 15%.

Labor Force Characteristics

Corresponding with upper middle class socio-economic characteristics of the County as a whole, a high percentage of the Contra Costa work force is employed in well-paying managerial and professional jobs. According to the 1980 U.S. Census, eight out of every ten workers who lived in Central County were employed in "white collar" jobs (professional, technical, sales, service or clerical positions), which represented 63% of all white collar workers in the entire County.

Conversely, in East County over one-third of the labor force was employed in the "operatives" occupational category, which includes many "blue collar" jobs. The West County sub-areas most closely resembles the occupations characteristics of the region as a whole; 28% of the workers in the five county San Francisco-Oakland area were employed in professional jobs in 1980, 36% in sales/clerical, 13% in service occupations, and 22% in the operative category.

Unemployment Rates

The unemployment rate for the Contra Costa civilian labor force was 5.8% at the time of the 1980 U.S. Census. It had risen to 7.0% in 1982 and 7.6% in 1983, but dropped 4.0% as of January 1, 1990 (Table 15), representing 17,100 unemployed persons, recording to EDD estimates. The unemployment rate for the County has consistently been slightly lower than the rate for the San Francisco-Oakland area and much lower than the rates for the state.

Recent employment rate estimates for individual cities in the County provided by EDD vary from a high of 7.4% in San Pablo and 6.6% in Richmond, to a low of 1.9% in Danville and 2.7% in Lafayette, San Ramon, and Walnut Creek. EDD predicts that unemployment may rise somewhat to the 4.5 to 5.0 range.

Table 15
Average Annual Unemployment Rates For
Contra Costa County and California
(1983 - 1990)

	Contra Costa County	California
1982	7.0%	10.0%
1983	8.0	9.7
1984	6.6	7.8
1985	5.9	7.2
1986	5.5	6.7
1987	4.9	5.8
1988	4.6	5.3
1989	4.0	---
1990	4.0	---

Source: California Employment Development Department. 1990 figure as of January 1, 1990.

Job Location of County Residents

As of January 1990, the labor force of Contra Costa County was approximately 422,300 workers, as compared to 292,700 jobs offered by local employers. This imbalance has existed for some time, as reflected in the commuting data complied by the 1980 U.S. Census. The majority of employed County residents in 1980 were employed within the County (59.3%). An additional 22.7% were employed in Alameda County and 12.9% were employed in San Francisco (Table 16). These figures may be compared to statewide totals. In 1980, 87% of the labor force in California worked in the same county as their residence, while in Contra Costa the portion was only 59%.

Table 16
Job Location of County Residents
1980

County of Employment	Number	Percent of Total
Contra Costa	159,651	59.3%
Alameda	61,189	22.7
San Francisco	34,658	12.9
Marin	1,464	0.5
San Mateo	3,574	1.3
Santa Clara	2,076	0.8
Solano/Other	6,524	2.4
Not Reported	30,260	----
Total	299,396	100.0

Note: Percentage distribution excludes those not reporting.

Source: U.S. Bureau of the Census

Based upon the responses from the census, West County residents were most likely to commute out of the County to their jobs (50% of the workers), compared to less than 20% of the East County residents who commuted out in 1980. The high percentage of West County residents who work outside the County may be partially explained by the close proximity of Alameda County employment centers such as Berkeley and Oakland.

Almost 25,000 residents commuted from West County south across the Contra Costa-Alameda County line to jobs elsewhere in the region in 1980, while a slightly larger number of residents (26,500) commuted to local jobs in the West County area. A relatively small number of West County commuters (1,010) travelled to jobs in Marin County.

As in the case of West County, a similarly high portion (49%) of the local workforce in the Lamorinda-Walnut Creek area of Central County commuted to jobs outside Contra Cost in 1980, with 42% of these workers employed in San Francisco or in the Berkeley-Oakland area. In the Concord-Martinez areas, only one third of the employed residents commute to jobs outside the County, with 25% of the total traveling to San Francisco and Oakland.

Employment Growth

Contra Costa County has continued to increase its share of Bay Area jobs from 7.1% in 1960, 7.7% in 1970, to 8.0% in 1980 (see Table 17). Contra Costa job growth this decade is only exceeded by Santa Clara and Alameda in the Bay Area, according to ABAG. ABAG in its November 1989 San Francisco Bay Area: 1900-2005 report estimates that Contra Costa County jobs will increase to 9.5% of Bay Area jobs in 1990 and 9.8% in 2005.

The economic development of Contra Costa County began with early agricultural uses throughout the County. Industrial development began to occur along the County's shoreline and near the railroad lines early in the 1890's, with oil refineries, steel fabricators and chemical firms the significant employers. During the 1940's the industrial base in West County grew significantly. West County is now a fully developed, mature industrial area with some redevelopment beginning to take place.

Since World War II, economic development of the County has generally proceeded from west to east, with a significant amount of activity now occurring in Central County. As the last vacant lands are developed in North Central County and the San Ramon Valley, pressures will intensify to develop more housing and commercial uses in East County.

Of the 292,700 jobs within Contra Costa County, according to ABAG, approximately 67% of the positions are now located in Central County, (see Table 19). Approximately 22% of Contra Costa's jobs are located in West County and 11% are in East County. While East Contra Costa is the fastest growing residential area, the number of jobs that have been created there have lagged well behind housing construction.

Table 17
Employment, Contra Costa County and Bay Area
1960-1990

	1960	1970	1980	1990
Contra Costa County	103,400	143,000	201,237	292,700
Bay Area	1,452,400	1,976,000	2,535,155	3,073,280

Source: California Employment Development Department; Association of Bay Area Governments.

Table 18
Employment Growth, 1960-1980

	Number	% Change
1960	103,400	
1970	143,000	38.3%
1980	201,237	40.7%
1990	292,700	45.9%

Source: Association of Bay Area Governments, 1974 report and Projections 90.

Table 19
Employment by SubArea
1990

	Number	Percent
West	65,070	22.2%
Central	195,550	66.8
East	32,080	11.0
Total	292,700	100.0

Source: Association of Bay Area Governments, Projections 90.

Since 1980, the employment base of Contra Costa County has grown by 91,463 jobs. Major increases have been registered in the professional "white collar" categories, largely as the result of a boom in office construction along the I-680 corridor. During the early and mid-1980's, commercial construction along the I-680 corridor in Central County added approximately 15 million square feet of new office space. This burst of office building was concentrated in Concord,

Walnut Creek, and San Ramon. In San Ramon, the Bishop Ranch Business Park was successful in attracting several very large corporations to relocate whole divisions of professional, clerical and data processing workers from their San Francisco headquarters.

Comparatively low land costs and the availability of a large labor pool continue to make Central County a desirable area for the establishment, expansion or relocation of existing businesses, although major corporate relocations slowed down in the mid and late 1980's as office rents in San Francisco became more competitive due to overbuilding.

The number of jobs in the "communications and utilities" category increased the most rapidly between December, 1980 and March 1988 by 363%, adding 13,600 jobs, with the "FIRE" category (financial, insurance, and real estate firms) more than doubling between 1980 and 1988, adding 13,800 positions (see Table 20). Most of the growth in the FIRE category, as well as in the TCU (Transportation, Communications, Utilities) industrial classification was associated with the relocations by several major corporations into the County (e.g. Bank of America and Pacific Bell). Business services grew by 9,800 positions and the "mining" category increased dramatically as a result of the relocation of the Chevron U.S.A. land exploration division to Concord.

Table 20 [1]
Contra Costa County Wage and Salary Employment by Industry
(1980-1990)

Industry	1980	% of 1988	1988	% of total	% Chng 80-88	1990 [2]
Agriculture	1,400	(0.7)	1,200	(0.4)	-14.3	1,100
Mining	600	(0.3)	2,900	(0.1)	383.3	3,400
Construction	13,300	(6.5)	20,600	(7.4)	54.9	20,900
Manufacturing	27,900	(13.6)	30,200	(10.9)	8.2	31,300
-chemicals & petroleum	10,000	(4.9)	13,500	(4.9)	35.0	14,400
-electronics and instrmnts3	4,300	(2.1)	3,800	(1.4)	-11.6	4,000
Transportation, Comm. Utilities	11,900	(5.8)	20,600	(7.4)	73.1	21,700
-communications & utl.	3,000	(1.5)	13,900	(5.0)	363.3	14,100
Wholesale Trade	8,800	(4.3)	10,900	(3.9)	23.9	11,400
Retail Trade	47,800	(23.3)	56,000	(20.2)	17.2	59,400
-restaurants and bars	12,300	(6.0)	26,000	(6.2)	40.7	18,300
Finance, Insurance, Real Estate	12,200	(5.9)	26,000	(9.4)	113.1	26,300
Services	41,400	(20.2)	67,700	(24.4)	63.5	77,700
-business services	9,200	(4.5)	19,000	(6.9)	106.5	23,100
-health services	11,800	(5.7)	17,700	(6.4)	50.0	19,900
Government	40,000	(19.5)	41,200	(14.9)	3.3	42,700
TOTAL	205,300		277,300		35.1	295,900

Source: California Employment Development Department, Annual Planning Information, Contra Costra County, June, 1989

Notes: (1) Because of changes made in classifying some jobs, the tools for 1980 can not be directly compared with later estimates in some categories. Totals do not include persons involved in labor-management trade disputes. Employment is for December of each year (not annual averages).
(2) Projections by EDD (March, 1988 benchmark)
(3) Includes some electrical equipment manufacturing which is not considered "high technology".

Office and residential construction in the County during the 1980's has pushed employment in the construction industry up to 20,600 persons. New construction and demand has also helped to sustain a very high rate of growth in the number of eating and drinking establishments and in health services. Restaurants,

bars, and other food service outlets added 5,000 jobs between the end of 1980 and 1988. Health services also grew significantly, increasing by 5,900 positions.

Surprisingly, County manufacturing continued to grow through the mid-1980's, with job losses in some older basic industries more than offset by gains in chemical and petroleum refining, printing and publishing activities. Much of the employment shifts in the manufacturing sector are due to fluctuations in the petroleum industry. During the first half of the decade, the County's oil refineries showed impressive growth, adding approximately 2,200 jobs between 1980 and 1985. However, during 1986 and 1987, approximately 500 workers were laid off, which was coupled with the continuing decline of other heavy industries such as the manufacturing of lumber and paper products, primary and fabricated metals, and other durable goods. Agriculture has declined by 14% since 1980, with a decrease of 200 jobs.

Employment Projections

The California Employment Development Department (EDD) estimates indicate that Contra Costa County jobs grew at a very fast rate (4.7%) during 1987, due primarily to office and related development, but that job growth will slow somewhat to 3.6% to 3.0% during 1988 and 1989. While over 10,000 new jobs were created in (or transferred into) the County between December, 1986 and December, 1987, and 12,500 new jobs added between December, 1987 and March, 1988, approximately 10,000 jobs were expected to be added during 1989 and about 8,600 jobs in 1990.

Almost three quarters of the new jobs expected during the nest two years will be in services and retail trade. The largest jump in workers (10,000 new full and part-time positions) will be in the broad services sector, which by the March 1988 had displaced retail trade as the biggest industrial category in the County, representing 78% of all County jobs. Business services are expected to add 4,100 positions over the 1989-1990 period, with the most dramatic increases occurring with the temporary help agencies that supply office and clerical workers. Approximately 2,200 new jobs are also anticipated in the health services field as a result of the John Muir Hospital expansion in Walnut Creek and the new San Ramon Valley Community Hospital. Retail trade is also expected to increase by 3,400 jobs in 1989 and 1990, reflecting plans for new retail stores including Sears at Hilltop Mall, Gottschalks in the new County East Mall, Raley's in Oakley, and Safeway in East County.

Twenty year employment projections have been prepared by the Association of Bay Area Governments (ABAG). The latest ABAG projection series (Projections '90) anticipates that the number of jobs in Contra Costa County will grow from approximately 232,500 in 1985 to approximately 334,710 positions in the year 1995 (see Table 21). The ABAG job projection is consistent with the amount of employment growth that is expected under the County's General Plan. The Land Use Element states that approximately 298,000 jobs are anticipated in the County after all of the commercial and industrial projects that have been approved by

the cities and County since 1985 are added to the existing employment base (see Table 18). Presumably, most of these recently approved and under construction projects will be finished by the early 1990's.

Table 21
Job Projections by Sub-Areas of
Contra Costa County

	1990	1995	Number & Percent Change	
West County	65,070	73,690	8,620	13.2%
North Central	141,260	156,280	15,020	10.6
Lamorinda	14,880	15,450	570	3.8
San Ramon Valley	37,850	47,152	9,302	24.6
Pittsburg-Antioch	27,410	33,380	5,970	21.8
Other East	6,230	8,757	2,527	40.6
Total	292,700	334,709	42,009	14.4

Source: ABAG, Projections 90; Contra Costa Community Development Department

IV. Housing Growth

The County's housing supply grew by 25.2%, or by 63,524 units between 1980 and 1990 (see Table 22). The most significant growth in absolute terms occurred in Central County, in which the supply increased by 30,636 units. The greatest growth rate, however, occurred in East County, which increased by 47.9%, compared to 18.2% and 22.1% in West and Central County, respectively. The housing in the unincorporated areas of the County has declined by 16.9% as areas have incorporated.

Table 22
Change in Housing Units by Sub Area
April 1, 1980 to January 1, 1990

	1980	1990	% change	Change in Units
West	71,835	84,902	18.2	13,067
Central	138,745	169,381	22.1	30,636
East	41,338	61,159	47.9	18,821
Total County	251,918	315,442	25.2	63,524

Source: Contra Costa County Community Development Department

Table 23
Distribution of Housing Units
by Sub-Area
(1980-1990)

	1980 Number	1980 Percent	1990 Number	1990 Percent
West	71,835	28.5	84,902	26.9
Central	138,745	55.1	169,381	53.7
East	41,338	16.4	61,159	19.4
Total County	251,918	100.0	315,442	100.0

Table 25 presents the growth in housing units over the last decade by unit type. Between 1980 and 1990, an average of 4,310 single family units (including condominiums) were added per year, 178 duplex-fourplex units were added per year, 1,775 appartment units in larger complexes (5 or more units) per year and 31 mobile homes annually. Apartment complexes increased to a larger proportion of the total County housing stock, from 15.7% to 18.2%.

Source: Contra Costa County Community Development Department

Table 24
Change in Housing Units
By Incorporated and Unincorporated Areas

	1980	1990	% Change	Change in Units
Incorporated Areas	180,798	256,353	41.8%	75,555
Unincorporated Areas	71,120	59,089	-16.9%	-12,031
Total County	251,918	315,442	25.2%	63,524

Source: Contra Costa County Community Development Department

Table 25
Housing Units by Type
(1980-1990)

	April 1, 1980	January 1, 1990	Increase by type
Single family	184,801 (73.4)	227,905 (72.4)	43,104 (68.5)
2-4 Units	21,438 (8.5)	23,216 (7.4)	1,778 (2.8)
5 Units	39,595 (15.7)	57,346 (18.2)	17,751 (28.2)
Mobile Homes	5,947 (2.4)	6,256 (2.0)	309 (0.5)
Total	251,781	314,723	62,942

Source: 1980 - U. S. Census
1990 - California Department of Finance, Demographic Research Unit

Table 26 indicates the level of growth in the housing stock in the unincorporated and incorporated areas of the County each year over the last decade. The following Table 27 provides a more detailed breakdown of new housing units produced each year over the last decade in each of the cities and unincorporated areas of the County.

The number of units produced per year in the County over the last decade has averaged about 6,400 units per year. Production has remained higher over the last five years, with an average of 8,500 units per year. The average number of units produced in the unincorporated areas of the County over the last ten years has been 1,527 units per year. Reflecting the higher production levels in the County overall, and average of 1,998 units have been produced per year in the unincorporated areas in the last five years (1985-1989).

Table 28 presents the number of rental units produced each year in the unincorporated and the incorporated areas of the County over the last decade. In Conta Costa County, department development of buildings with five or more units has fallen 35% in the three years since 1986. Residential development has occurred primarily in Antioch, Concord, Hercules, Monterey, Pittsburg, Pleasant Hill, Richmond, San Ramon, Walnut Creek and the unincorporated areas of the County. The areas with no or minimal multifamily development were Brentwood, Clayton, Danville, Lafayette, Moraga and Orinda, all of which did have other types of development during this period (see Table 25).

Homebuilding during the 1980's has fluctuated from one year to the next, consistent with the national economic climate. Residential construction began a nosedive during the early 1980's when very high interest rates and a national recession caused housing completions to reach their lowest point in 1982. By the end of 1984, however, the local homebuilding industry had recovered and the last half of the decade has seen a substantial increase in construction. Peak construction levels occurred in 1987, apparently due to lower interest levels and increased multifamily production resulting from the flurry of project proposals prior to the implementation of the 1986 Tax Reform Act which eliminated many of the tax incentives for rental housing ownership. (See Table 29).

TABLE 26

Annual Growth in Housing Units in Incorporated and Unincorporated Areas
by Four Sub-Areas of Contra Costa County

	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	Total 1980-90
East County	1,743	1,438	732	1,131	989	2,101	2,775	3,381	2,663	2,868	19,821
Inc.	957	969	535	775	478	1,561	2,058	2,005	1,718	1,803	12,859
Uninc.	786	469	197	356	511	540	717	1,356	945	1,065	6,942
North Central County	1,882	1,762	1,133	973	1,932	2,258	2,648	2,925	2,305	1,838	19,656
Inc.	1,560	1,402	937	802	1,785	2,158	2,239	2,423	1,476	1,375	16,157
Uninc.	322	360	196	171	147	100	409	502	829	463	3,499
San Ramon Valley	1,334	739	377	389	1,346	720	1,002	1,970	1,774	1,329	10,983
Inc.	1,025	535	270	198	980	352	350	1,578	1,361	761	7,410
Uninc.	309	204	107	194	366	368	652	392	413	568	3,573
West County	1,281	692	349	647	830	1,179	1,365	2,867	1,964	1,893	13,067
Inc.	1,044	531	288	623	729	1,082	1,313	2,519	1,890	1,812	11,831
Uninc.	237	161	61	24	101	97	52	348	74	81	1,236
Inc.	4,586	3,437	2,030	2,395	3,972	5,153	5,960	8,525	7,112	5,750	48,920
	(73.5)	(74.2)	(78.3)	(76.3)	(77.9)	(82.3)	(76.5)	(76.5)	(75.9)	(72.6)	(76.2)
Uninc.	1,654	1,194	561	745	1,125	1,105	1,830	2,618	2,261	2,177	15,270
	(26.5)	(25.8)	(21.7)	(23.7)	(22.1)	(17.7)	(23.5)	(23.5)	(24.1)	(27.4)	(23.8)
TOTAL	6,240	4,631	2,591	3,140	5,097	6,258	7,790	11,143	9,373	7,927	64,191

Source: Contra Costa Community Development Department

TABLE 27

ANNUAL GROWTH IN HOUSING UNITS
BY JURISDICTION IN CONTRA COSTA COUNTY (1)
(1980 - 1990)

	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	Total 1980-90
EAST COUNTY											
Antioch	478	361	273	462	267	865	1,197	1,105	895	1,040	6,943
Brentwood	36	79	16	5	15	100	327	118	151	68	916
Pittsburg	443	529	246	308	196	596	534	781	672	695	5,000
W. Pittsburg (uninc)	188	223	20	75	94	137	304	583	307	60	1,991
Oakley (uninc)	300	80	73	214	307	234	335	518	360	651	3,072
Disco Bay (uninc)	187	139	92	44	112	154	62	258	252	304	1,604
Other unincorp.	111	27	12	23	(2)	15	16	17	26	50	295
Sub-total	1,743	1,438	732	1,131	989	2,101	2,775	3,381	2,663	2,868	19,821
NOTH CENTRAL COUNTY											
Martinez	240	360	199	239	1,020	371	210	481	191	120	3,431
Concord	450	272	370	280	314	841	788	766	437	299	4,817
Clayton	99	0	2	19	63	54	3	7	28	89	364
Pleasant Hill	343	292	210	135	67	311	514	724	373	187	3,156
Walnut Creek	233	331	96	85	210	385	591	233	251	500	2,915
Lafayette	85	47	31	13	27	25	27	65	45	68	433
Moraga	62	40	4	5	58	136	86	103	98	61	653
Orinda (2)	48	60	25	26	26	35	20	44	53	51	388
Other unincorp.	322	360	196	171	147	100	409	502	829	463	3,499
Sub-total	1,882	1,762	1,133	973	1,932	2,258	2,648	2,925	2,305	1,838	19,656
SAN RAMON VALLEY											
Alamo (uninc)	40	63	24	27	56	57	78	120	158	191	814
Danville (3)	425	310	125	63	250	155	124	361	273	107	2,193
San Ramon (4)	600	225	145	135	730	197	226	1,217	1,088	654	5,217
Blackhawk (uninc)	110	110	80	120	307	268	266	268	251	364	2,144
Other unincorp. (5)	159	31	3	44	3	43	308	4	4	13	612
Sub-total	1,334	739	377	389	1,346	720	1,002	1,970	1,774	1,329	10,980
WEST COUNTY											
El Cerrito	41	30	(1)	36	48	145	25	20	200	52	596
Richmond	449	216	46	211	237	279	665	1,482	716	667	5,068
San Pablo	249	222	31	133	81	114	11	257	-3	27	1,122
Pinole	30	60	42	91	90	92	134	289	255	450	1,533
Hercules	275	3	70	152	273	452	478	471	722	616	3,512
Other unincorp.	237	161	61	24	101	97	52	348	741	81	1,903
Sub-total	1,281	692	349	647	830	1,179	1,365	2,867	2,631	1,893	13,734
COUNTY TOTAL	6,240	4,631	2,591	3,140	5,097	6,258	7,790	11,143	9,373	7,928	64,191

Source: Contra Costa County Community Development Department

TABLE 28

APARTMENT UNITS* ADDED BY YEAR (1980-1990)

	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	Net 80-90
Antioch	63		100	122	-10	321	212	160	-6	74	1,036
Brentwood								10			10
Clayton											0
Concord	-61	20	224	68	24	87	449	450	241	54	1,339
Danville					6	8			0		14
El Cerrito	17	8		16	5	99			168	26	339
Hercules				21	24	125	145	161	350	197	1,026
Lafayette								13			13
Martinez	5	234			476	72	30	332	8		1,157
Moraga											0
Orinda											0
Pinole							18	98	8	42	166
Pittsburg					-16	434	430	486	608	310	2,252
Pleasant Hill	184		5		4	144	216	418	16		987
Richmond	5	25	3		28	21	403	1,155	305	230	2,175
San Pablo	61	228	54	110	90	113	8	238			902
San Ramon					508	40	102	700	502	240	2,092
Walnut Creek	16	182	36		22	28	394	90	70	246	1,084
Unincorporated	299	125	32	24	36	88	121	898	864	226	2,713
Total Units Built	797	822	454	351	1,223	1,583	2,528	5,209	2,923	1,645	17,545
Total Units Converted or demolished	-208	[illegible]			-26				-6		-240
Total Net Add.	589	822	454	361	1,197	1,583	2,528	5,209	2,917	1,645	17,305

Source: Contra Costa County Community Development Department

*Apartments are defined as units in buildings containing five or more dwelling units.

1 Data may be incomplete for Danville in 1988.

Table 29
Annual Growth in Housing Units by Type, 1980-1989

Year	Single Family	2-4 Units	5+ Units	Mobile Homes	Total
1980	4,172	240	674	66	5,152
1981	3,585	148	640	52	4,425
1982	1,859	180	487	24	2,550
1983	2,702	118	239	175	3,234
1984	3,930	185	1,381	1	5,497
1985	4,449	153	1,676	6	6,284
1986	4,869	179	2,618	-100	7,566
1987	6,865	141	4,292	13	11,311
1988	4,536	207	3,805	10	8,658
1989	6,020	220	1,939	32	7,927
TOTAL	42,987	1,771	17,751	279	62,788

Source: California Department of Finance, Demographic Research Unit, as of April of each year.

V. Population and Household Characteristics

Population

In 1990, Contra Costa County's population is 802,933, with 154,615 (or 19.2%) in the County's unincorporated areas. Table 30 presents the 1990 population figures for the unincorporated areas and each city of the County.

Table 30
Contra Costa County
Population by Area (As January 1, 1990)

	NUMBER	PERCENT
West County		
El Cerrito	23,374	2.9
Hercules	16,892	2.1
Pinole	16,949	2.1
Richmond	84,344	10.5
San Pablo	21,612	2.7
Unincorporated	49,000	6.1
Subtotal	212,171	26.4%
Central County		
Clayton	6,901	0.9
Concord	111,332	13.7
Danville	31,601	3.9
Lafayette	23,305	2.9
Martinez	30,999	3.9
Moraga	16,373	2.0
Orinda	17,751	2.2
Pleasant Hill	32,296	4.0
San Ramon	35,966	4.5
Walnut Creek	63,868	8.0
Unincorporated	56,615	7.0
Subtotal	427,007	53.2%
East County		
Antioch	62,032	7.7
Brentwood	7,060	0.9
Pittsburg	45,663	5.7
Unincorporated	49,000	6.1
Subtotal	163,755	20.4%
Total Incorporated	648,318	80.7%
Unincorporated	154,615	19.3%
Total County	802,933	100.0%

Source: California Department of Finance; Community Development Department

Households

Table 31
Number of Households by Sub-Area of the County
January, 1990

	Number	Percent
West County	81,230	26.7%
Central County	164,734	54.1
East County	58,660	19.2
Incorporated Areas	247,313	81.2
Unincorporated Areas	57,311	18.2
Total County	304,624	100.0

Source: California Department of Finance; Community Development Department

Contra Costa County households have increased in number from 241,418 in 1980 to 304,624 in 1990. Of these households, 18.2% or 57,311 households reside in the unincorporated areas of the County (see Table 31).

Household Size

In the decade between 1970 and 1980, the average household size declined by 0.5 persons within Contra Costa County (Table 32). Central County experienced the greatest decline (0.62 persons per household). East County had the smallest reduction in household size and in 1980 had an average household size considerably larger than West or Central County. The household size has continued to decline since 1980 as shown by the estimates for 1990.

Table 32
Average Household Size
by Sub-Area of the County

	1970	1980	1990*
West	3.04	2.63	2.54
Central	3.29	2.67	2.53
East	3.20	2.85	2.71
Total	3.19	2.69	2.57

Source: U.S. Bureau of the Census from ABAG Projections 90 data

*Estimated by Contra Costa County Community Development Department

Table 33 estimates average household sizes estimated for each city in Contra Costa ranging from the smallest average household size of 2.14 in Walnut Creek and the largest household size of 2.91 in Hercules.

Table 33
Average Household Size by
City and Area of the County
(1990)

	Persons Per Household
West County	
El Cerrito	2.26
Hercules	3.11
Pinole	2.79
Richmond	2.54
San Pablo	2.39
SUBTOTAL	2.54
Central County	
Clayton	2.97
Concord	2.52
Danville	2.89
Lafayette	2.52
Martinez	2.50
Moraga	2.64
Orinda	2.63
Pleasant Hill	2.34
San Ramon	2.93
Walnut Creek	2.71
SUBTOTAL	2.53
East County	
Antioch	2.72
Brentwood	2.85
Pittsburg	2.74
Rural East	2.63
SUBTOTAL	2.71
TOTAL COUNTY	2.57

Source: State Department of Finance

ABAG estimated that households will continue to decline to 2.57 in 1990, 2.54 in 1995, with a continuing decline to 2.46 in the year 2005. This trend indicates that the demand for new housing units should be shifting away from the large single family detached home to a smaller single family home or condominium.

Income

The U.S. Department of Housing and Urban Development (HUD) produces median household income figures adjusted by household sizes approximately every year (see Table 34).

Table 34
1990 Median Income Levels

Household Size	Very Low	Low	Moderate
1 Person	$15,750	$24,700	$37,100
2 Person	18,000	28,250	42,350
3 Person	20,250	31,750	47,650
4 Person	22,500	35,300	52,900
5 Person	24,300	37,500	56,200
6 Person	26,100	39,700	59,500
7 Person	27,900	41,950	62,800
8 Person	29,700	44,150	66,200

Source: U. S. Department of Housing and Urban Development figures released February, 1990 for Oakland PMSA (Alameda and Contra Costa Counties) based on a median income of $44,100 for a family of four.

According to HUD 1990 median income figures, the Oakland Primary Metropolitan Statistical Area, which includes Alameda and Contra Costa Counties, ranked sixth in the state after the San Jose, Anaheim-Santa Ana, Santa Barbara-Santa Maria-Lompoc, San Francisco, and Oxnard-Ventura metropolitan statistical areas. While Contra Costa County is located in one of the more affluent areas of the state, it is important to note the disparities in incomes for different populations within the County.

A look at various populations within the County reveals a vast difference in economic status. 1980 census data provides a basis for comparison of different populations (See Table 35). For example, the median income for renter households was half (50.2%) the median income of owner occupant households. Incomes also varied by ethnicity. White households had a median income that was 66% higher than Black households, 27% higher than American Indian households, and 19% higher than households of Spanish origin, but 12% lower than Asian and Pacific Islander households. Female headed households with children had mean incomes that were 40% of those of families with children overall.

Table 35
Average Income Levels for Different County Populations

By Household Types	Median	Mean
Households	$22,870	$26,539
Families	26,510	31,268
Unrelated Individuals	10,152	12,740
Families with Children		29,711
Female Headed Households with Children		11,751
By Housing Tenure		
Owner-occupant Households	27,649	31,144
Renter-occupant Households	13,866	16,334
By Ethnicity		
White	23,777	27,562
Black	14,275	17,743
American Indian	18,699	20,588
Asian and Pacific Islander	27,070	28,730
Spanish Origin	20,005	21,971

Source: U.S. Bureau of Census, 1980.

Table 36
Populations Below Poverty Level

	Number Below Poverty Level	% Below Poverty Level	Total Population
Persons	49,086	7.5%	656,380
Families	10,860	6.1%	178,295
Households	17,800	7.4%	241,418
Female Headed Families	5,696	24,5%	23,221
Female Headed Families with Children under 18	5,288	31.0%	17,048
Population 65+	3,811	6.6%	57,731
Children under 18	17,770	10.0%	177,447

Source: U.S. Bureau of the Census, 1980.

*Note different than age distribution due to sampling.

Poverty level incidence rates for different populations also reveal the level of economic distress among different populations (see Table 36). In 1980, 49,086 persons in Contra Costa County had incomes below the poverty level, or 7.5% of the total population. The neediest groups in Contra Costa County in terms of poverty status appear to be female headed households, particularly those with children, and single, unrelated individuals. There were 5,696 female headed households with incomes below poverty levels in 1980, which represents 23.2% of all female headed households. In comparison, only 6.1% of families have incomes below poverty level. Almost a third of female headed households with children under 18 years old had incomes below poverty levels.

Not surprisingly, homeowner, or owner-occupant, households have generally higher income than renter households. In 1980, only 10.3% of the county's homeowners had incomes of less than $10,000, while 34.7% of the renter households had incomes less than $10,000 (Tables 37 and 38). West County had the highest proportion of lower income homeowners within the county (16.3% had incomes of less than $10,000). In Central County, only 6.3% of the homeowners had incomes of less than $10,000 in 1980. Nearly three quarters (72.4%) of the county's homeowners had household incomes of $20,000 or more as compared to 31.2% of the renters.

Table 37
Income Distribution
of Homeowners

	$0 to $4,999	$5,000 to $9,999	$10,000 to $14,999	$15,000 to $19,999	$20,000+	All Owners
West	6.2%	10.1%	9.5%	12.4%	61.8%	100.0%
Central	2.2	4.1	5.9	7.4	80.4	100.0
East	4.0	7.9	9.5	11.9	66.7	100.0
Total County	3.7	6.6	7.6	9.7	72.4	100.0

Source: U.S. Bureau of the Census, 1980.

Table 38
Income Distribution
of Renters

	$0 to $4,999	$5,000 to $9,999	$10,000 to $14,999	$15,000 to $19,999	$20,000+	All Owners
West	18.9%	22.4%	19.3%	15.1%	24.3%	100.0%
Central	10.2	17.3	17.9	16.2	38.4	100.0
East	22.4	21.6	21.1	13.3	21.6	100.0
Total County	15.0	19.7	18.4	15.7	31.2	100.0

Source: U.S. Bureau of the Census, 1980

As reported in the 1980 census, there were significant regional differences in the county, with West County households reporting a median income of $18,808, East County reporting $19,509, and Central County reporting a median household income of $26,794, compared to a median household income of $22,875 countywide (See Table 39).

Table 39
Number and Distribution of Households by Income
(1980)

Income	West	%	Central	%	East	%	County	%
0 - $9,999	18,555	26.6	18,448	13.9	9,572	24.8	46,575	19.3
10,000-19,999	18,186	26.1	27,464	20.6	10,357	26.8	56,007	23.2
20,000-29,999	16,085	23.1	29,474	22.1	10,058	26.0	55,617	23.0
30,000-39,999	9,220	13.2	25,600	19.2	5,353	13.8	40,173	16.6
40,000+	7,610	10.9	32,117	24.1	3,319	8.6	43,046	17.8
Total Households	69,656	99.9	133,103	99.9	38,659	100.0	241,418	99.9
Median Income	$18,808		$26,794		$19,509		$22,875	

Source: U.S. Bureau of the Census, 1980

While ABAG 1990 household income data differs greatly from HUD 1990 data, it does provide disaggregated income estimates for cities and unincorporated areas of Contra Costa County (see Table 40). According to ABAG, Alamo/Blackhawk and Orinda far surpass other areas with mean income levels of $91,500 and $91,300, respectively, in 1990. San Pablo, Pittsburg and Richmond ranked lowest in terms of mean income levels.

Table 40
1990 Mean Household Income by Area of County

Antioch	43,100
Brentwood	41,100
Clayton	62,000
Concord	44,200
Danville	76,500
El Cerrito	49,100
Hercules	59,600
Lafayette	68,200
Martinez	46,100
Moraga	72,000
Orinda	91,300
Pinole	49,400
Pittsburg	35,400
Pleasant Hill	47,000
Richmond	36,200
San Pablo	29,200
San Ramon	67,000
Walnut Creek	53,300
Alamo-Blackhawk	91,500
Rodeo-Crockett	39,500
Rural East County	45,100
Remainder	69,800
Total County	49,600

Notes: All areas are City Spheres of Influence, with the exception of San Ramon, Walnut Creek, Alamo-Blackhawk, Rodeo-Crockett, and Rural East County.

Source: Association of Bay Area Governments, Projections 90.

In the period from 1978 to 1985, Contra Costa County median adjusted gross income failed to keep up with inflation. Real median adjusted gross income declined by 17% due to a rapid rise in the cost of living. At the same time, average adjusted gross income, which is more skewed by extremes in values, increased at 16.5% over inflation, indicating that upper echelon wage earners have experienced wage increases. At the same time, the number of individuals in the lowest income levels increased the most rapidly. As Table 41 indicates, even when adjusted for inflation, the lowest income group earning less than $14,000 per year in 1985 dollars increased by 37%. This indicates an increasing need for housing affordable to very low income households.

Table 41
Impact of Inflation and Sluggish Income Growth
On the Total Number of Individuals Reporting Adjusted Gross Incomes
Contra Costa County

Income Class (Constant 1985)	1978	1985	Percentage Change (78-85)
$ 0-14,000	70,502	96,663	37.0%
$ 14,000-24,000	41,209	53,538	29.9%
$ 24,000-36,000	43,204	51,023	18.1%
$ 36,000-50,000	41,341	43,630	5.5%
$ 50,000-75,000	33,402	38,116	14.1%
$ 75,000 >	15,414	20,058	30.1%
Total Returns	245,072	303,028	23.6%

Source: California Franchise Tax Board; Association of Bay Area Governments

Actual state taxable incomes from all returns in 1985 show that approximately one-third of Contra Costa County taxpayers earned less than $14,000 in 1985 (See Table 41).

According to the Association of Bay Area Governments (ABAG), Contra Costa County experienced one of the lowest rates of household income growth of the nine Bay Area Counties, at 12.9% compared to a Bay Area average of 13.9% increase from 1985 to 1988. When adjusted for inflation, region wide household income growth has stagnated, with a growth of only 3.2% from 1985 to 1988. ABAG estimates that 40% of that growth is due to an increased number of workers per household rather than increases in wages. In Contra Costa County, household incomes have increased only 2.2% over the same time period when adjusted for inflation, with 41% of that increase due to increased labor force participation. In November of 1988, ABAG estimated that mean household incomes in Contra Costa County rose from $42,500 to $47,975. Antioch and San Ramon had the greatest increases in household incomes at 16.6% and 15.5% increases, respectively, from 1985 to 1988, with Martinez, Clayton and Pinole experiencing the lowest increases in household income at 10.7%, 10.8% and 10.9%.

According to ABAG, Contra Costa County had experienced the greatest increase in income inequality within the Bay Area region from 1978 to 1985, with a rapid increase in incomes for higher income brackets (see Table 42). This is attributed to wage increases in the managerial and professional classes in Central County, particularly Orinda, Lafayette, Walnut Creek, Danville and San Ramon. Unfortunately, incomes for the remaining 75% of the labor force have not kept pace with inflation during this period.

Table 42
Percent Distribution and Change of Contra Costa County's Taxable Income
Taxable Years 1978 - 1985: Total Returns
(in 1985 Dollars)

Adjusted Gross Income Class	Percent 1978	1979	1980	1981	1982	1983	1984	1985
$ 0-14,000	44.97	43.62	40.83	38.47	35.83	34.24	32.76	31.89
$ 14,000-24,000	24.31	22.18	20.79	19.62	19.18	18.66	18.24	17.67
$ 24,000-36,000	18.04	18.40	19.08	18.75	18.69	18.14	17.53	16.84
$ 36,000-42,000	5.30	6.05	6.26	6.73	6.86	6.81	6.89	6.81
$ 42,000-50,000	3.41	4.46	5.58	6.59	7.05	7.39	7.51	7.59
$ 50,000-75,000	1.70	2.29	5.35	7.23	8.93	10.34	11.58	12.58
$ 75,000+	2.26	3.00	2.11	2.61	3.46	4.41	5.48	6.62
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

Source: State of California, Franchise Tax Board, Annual Report; Association of Bay Area Governments

HUD median household income figures increased at a rapid rate during the first part of the decade, but have slowed in recent years, with an average increase between 1980 and 1990 of 6.7% per year (see Table 43). These household income figures have increased almost 43% between 1980-85. Between 1985 and 1990, incomes have increased at a slower cumulative rate of 32%. Between 1980 and 1990, median incomes have increased 88.7%.

Table 43
Annual Median Household Income Increases

	Income Level	Annual Increase	Cumulative Increases 1980-85	1985-90
1980	$23,375	12.9%		
1981	27,187	16.3		
1982	30,500	12.2		
1983	31,600	3.6		
1984	32,000	1.3		
1985	33,375	4.3	42.8	
1986	N/A	0.0		
1987	36,700	10.0		
1988	40,100	9.3		
1989	42,400	5.7		
1990	44,100	4.0		32.1

Source: U.S. Department of Housing and Urban Development for Oakland PMSA (Alameda and Contra Costa Counties) for family of four.

Age Distribution

Reflecting national and state trends, the Contra Costa County population is aging. The median age of the county's population has increased from 27.8 in 1970 to 31.5 years in 1980 (Table 44). ABAG projections indicate that the median age will continue to increase to 37.5 years of age by 2005.

The percentage of the population under age 19 decreased from about 36% of the total population in 1970 to 31% in 1980. The proportion of children making up the County's population is expected to decrease to approximately 24.7% in the year 2005. Conversely, the proportion of the population aged 65 and over increased from 6.9% in 1970 to 9.3% in 1980. This age group is expected to increase to 11.3% of the population by the year 2005.

Table 44
Age Distribution

	1970	1980	Projected 1990	Projected 1995	Projected 2005
Under 5	8.3%	6.7%	6.6%	6.5%	6.0%
5-19	27.8	24.4	20.1	19.4	18.7
20-64	56.9	59.6	63.4	64.0	64.1
65 and over	6.9	9.3	9.9	10.1	11.3
Total Number	558,389	656,380	790,200	861,000	946,900
Median Age	27.8	31.5	33.7	35.0	37.5

Source: U.S. Bureau of the Census; ABAG, Projections 90.

East County had the youngest population of any sub-area of the county in 1980; 31.7% of the population was below the age of 18 compared to 27.6% for the entire county (see Table 45). West County had the highest proportion of elderly, with 10.2% of its population aged 50 years or older, compared to 9.3% in the County overall.

The median age structure of the three areas of the county differed only to a small degree in 1980, although there wide variations among individual communities (Table 43). West County had the highest proportion of elderly, with 10.2% of its population aged 65 years or older compred to 9.3% in the County overall. However, in West County, median age varied widely from Kensington (41.0) and El Cerrito (40.1) to Hercules (28.4) (Tables 46 and 47). Central County had a range from Walnut Creek (39.6) and Orinda (38.5) to Concord (29.6), and East County median ages ranged from a county high on Bethel Island (48.6) to Oakley (25.9) and Antioch (27.8).

Table 45
Age Distribution
by Sub-Areas
(1980)

	West	Central	East	County
Under 5	7.2%	5.7%	9.2%	6.7%
5-17	19.9	20.9	22.5	20.9
18-64	62.7	64.3	60.1	63.2
Over 65	10.2	9.1	8.2	9.3
Total Number of Persons	184,151	361,392	110,827	656,380
Median Age	31.3	32.6	29.6	31.5

Source: U.S. Bureau of the Census

Table 46
Median Age of Population
in Unincorporated Communities
(1980)

Area	Median Age	Percent Over 65
Alamo	36.3	5.8
Bethel Island	48.6	19.7
Discovery Bay	34.6	3.2
El Sobrante	31.5	6.8
Kensington	41.0	16.7
Oakley	25.9	7.1
Rodeo	29.2	7.6
Sand Hill	30.7	10.5
Tara Hills-Montalvin Manor	29.1	4.5
Vine Hill-Pacheco	28.3	5.3
West Pittsburg	29.0	9.8

Source: U.S. Bureau of the Census, 1980.

Table 47
Median Age of Population
in Incorporated Cities
(1980)

City	Median Age	Percent Over 65
Antioch	27.8	7.5
Brentwood	29.4	11.9
Clayton	31.6	3.0
Concord	29.6	7.3
Danville	33.4	4.9
El Cerrito	40.1	15.9
Hercules	28.4	2.6
Lafayette	35.9	10.0
Martinez	31.4	8.5
Moraga	34.5	5.7
Orinda	38.5	8.2
Pinole	31.3	4.9
Pittsburg	27.1	7.4
Pleasant Hill	31.5	8.5
Richmond	30.0	10.5
San Pablo	28.9	11.6
San Ramon	30.1	3.5
Walnut Creek	39.6	20.2
County	31.5	9.3

Source: U.S. Bureau of the Census, 1980.

Table 48
Contra Costa County Population
by Age and Sex

	1980		1990		1995		2005	
Age	Male	Female	Male	Female	Male	Female	Male	Female
0-4	22,421	21,614	26,900	25,500	28,500	27,000	29,000	27,400
5-19	81,365	78,505	80,800	77,700	84,700	81,900	90,100	87,200
20-64	191,437	200,194	247,400	253,500	272,600	279,200	298,700	307,900
65+	24,875	35,969	33,800	44,600	37,800	49,300	47,700	58,900
Median	30.13	31.80	33.07	34.24	34.46	35.53	36.92	38.00

Source: Association of Bay Area Governments, Projections 90.

Educational Distribution

The educational level of Contra Costa residents was relatively high in 1980. Almost half of the population aged 25 and over (49.4%) in the county in 1980 had some college education and 25.5% had graduated from college (Table 49). This compares with the State of California in which 42% of the residents aged 25 and over had some college education and 19.6% had graduated from college.

Educational attainment was the highest in Central County where 58.2% of those over 25 had some college education and only 10.7% had not graduated from high school. East County had the highest percentage of those who had not graduated from high school (30.8%), a rate which was almost three times the proportion in Central County.

Table 49
Highest Level of Education
for Persons 25 or More Years of Age
(1980)

	West	Central	East	Total County	State of California
Elementary	12.8%	4.3%	15.9%	8.5%	14.2%
High School 1-3	13.6	6.4	14.9	9.8	12.3
High School 4	33.0	30.2	38.8	32.3	31.4
College 1-3	21.7	26.2	19.8	23.9	22.4
College 4+	18.9	32.9	10.6	25.5	19.6
Total Number Of Persons	112,864	225,133	62,361	400,358	14,043,986

Source: U.S. Bureau of the Census.

Ethnic Distribution

As the County has grown, it has become more racially diverse. In 1940, less than 5% of the County's population was of minority origin; whereas by 1980, 18.5% of the County was of minority origin (see Table 50). 1985 Census data indicates that Hispanic population has increased from 8.3 to 9.2% of the County's population between 1980-85, representing an increase from 54,600 to 67,100 people. Census data for "other races" indicates that that population grew from 37,400 in 1980 to 59,000 in 1985, or from 5.7 to 8.1% of population, mostly due to immigration.

The racial composition of the population varies by area of the County. While 81.5% of the total County population was in the "white" category in 1980, the percentage was 60.5% in West County and 92.9% in Central County. West County had the highest proportion of blacks (25.7%), while East County and Central County had 7.8% and 1.2%, respectively. West County also has the highest

proportion of Asians, 7.5% versus 4.7% for the total County. The area with the largest proportion of Spanish Origin population was East County (17.2%), while the percentage for the County overall was 8.5%.

Table 50
Racial Composition
by Sub-Area of the County
(1980)

	West	Central	East	Total County
White	111,438 (60.5%)	335,605 (92.9%)	87,585 (79.0%)	534,628 (81.5%)
Black	47,287 (25.7)	4,278 (1.2)	8,607 (7.8)	60,172 (9.2)
American Indian Eskimo & Aleut	1,304 (0.7)	1,510 (0.4)	1,076 (1.0)	3,890 (0.6)
Asian	13,780 (7.5)	12,944 (3.6)	3,839 (3.5)	30,563 (4.7)
Other Races	10,342 (5.6)	7,055 (2.0)	9,730 (8.8)	27,127 (4.1)
Total	184,151 (100)	361,392 (100)	110,837 (100)	656,380 (100)
Spanish Origin	18,125 (9.9)	18,668 (5.2)	19,027 (17.2)	55,820 (8.5)

Source: U.S. Bureau of the Census, 1980.

Note: Spanish Origin may include other racial categories.

Projections by the Association of Bay Area Governments and the California Department of Finance indicate that the overall portion of minorities in Contra Costa County is expected to increase during the 1980's, due primarily to the influx of Asian families and other non-Black, non-Hispanic ethnic residents which are counted in the "Other Races" category (see Table 51). While the number of blacks in the County is expected to rise from approximately 60,000 residents in 1980 to an estimated 87,000 population in 1990, the number of Asians, Pacific Islanders, American Indians, and "other" residents should grow from about 62,000 to a projected 100,000 residents.

Table 51
Projected Racial Composition in Contra Costa County (1990)

	Population	% of Total
White (incl. Hispanic)	590,000	75.9%
Black	87,000	11.2
Asian-Pacific/Other	100,000	12.9
Total	777,000	100.0

Source: Association of Bay Area Governments; California Department of Finance.

Specific communities have pockets of high concentrations of minority populations (see Table 52). For example, Pittsburg and Richmond's populations were 20% and 48% Black, respectively, while Hercules had 37% Asian and Pacific Islander, and Brentwood had 40% of the population made up of persons of Spanish Origin.

Table 52
Racial Percentage Distribution by Community (1980)

Jurisdiction	Total Population	White	Black	Am. Indian, Eskimo, & Aleut	Asian & Pacific	Other	Spanish Origin*
Antioch	42,683	89.45%	1.23%	1.02%	2.20%	6.10%	14.84%
Brentwood	4,434	75.73	0.07	0.97	1.62	21.60	39.54
Clayton	4,325	94.57	1.04	0.46	2.54	1.39	4.74
Concord	103,251	90.53	1.67	0.55	4.49	2.76	7.20
El Cerrito	22,731	71.41	9.70	0.26	16.18	2.45	4.65
Hercules	5,963	45.70	12.36	0.42	36.63	4.90	10.77
Lafayette	20,879	95.44	0.42	0.19	2.88	1.08	2.65
Martinez	22,582	91.67	1.97	0.63	3.05	2.68	7.64
Moraga	15,014	92.82	0.90	0.09	4.51	1.69	3.03
Pinole	14,253	86.88	4.27	0.83	5.02	3.00	7.78
Pittsburg	33,034	61.39	20.19	0.74	6.78	10.89	18.78
Pleasant Hill	25,124	93.36	1.05	0.43	3.06	2.10	5.57
Richmond	74,676	39.72	47.94	0.61	4.88	6.85	10.33
San Pablo	19,750	68.41	15.80	1.28	4.56	9.95	16.99
Walnut Creek	53,643	93.72	0.75	0.23	3.91	1.40	3.31
Unincorporated	194,034	88.87	3.82	0.64	3.41	3.27	7.46
Contra Costa County	656,380	81.45	9.17	0.59	4.66	4.13	8.50

* "Persons of Spanish Origin" is not considered a racial identity; some are listed as white race, Spanish origin, etc.

Source: U.S. Bureau of Census, 1980

Disabled Populations

Precise figures on the number of physically handicapped are not available. According to the 1980 census, of the Contra Costa County population over age 65, 14.2% had disabilities which prohibited them from using public transportation (Table 53). This percentage was higher in East County (19.0%) and West County (16.7%). Of the population aged 16-64, 4.5% had work disabilities and were not in the labor force (Table 54). The proportions of the working age population in this category were also the highest in East County and West County. An additional 2.9% of the working age population had work disabilities but were in the labor force.

Table 53
Public Transportation Disability for the Population Aged 16-64 and 65+ and Percent of Total by Sub-Area of the County (1980)

	16-64	% of Total	65+	% of Total
West	3,283	2.7%	3,027	16.7%
Central	2,649	1.1	3,811	12.3%
East	1,476	2.1	1,344	19.0
Total County	7,408	1.7	8,192	14.2

Source: U.S. Bureau of the Census, 1980.

Table 54
Work Disability of Population Aged 16-64 (1980)

	In Labor Force	% of Population Age 16-64	Not in Labor Force	% of Population Age 16-64
West	3,953	3.2%	9,201	7.5%
Central	6,611	2.7	6,682	3.1
East	2,558	3.6	5,107	7.2
Total County	13,122	2.9%	21,990	4.5%

Source: U.S. Bureau of the Census, 1980.

Female Headed Households

Over 24% of the households in Contra Costa County were headed by a female in 1980 (Table 55). The percentage of female-headed households was as low as 21.7% in East County and as high as 29.5% in West County. In West County, 9.1% of the households were female-headed with children in 1980, as compared to 5.0% in Central County. Women tend to work in lower paid occupations and even when in the same occupations as men are generally lower paid. According to a report prepared by the California Employment Development Department, in Contra Costa County women earn 53% of men's earnings compared to 59% nationwide. Women make up the majority of the county's economically disadvantaged population and often have minor children for which they are responsible. A high proportion (72%) of the Section 8 subsidized housing program is used to provide housing for female headed households within the county.

Table 55
Number and Frequency of
Female Headed Households
(1980)

	Number of FHH	% of Total Households	Number of FHH With Children	% of Total Households
West	20,536	29.5%	6,354	9.1%
Central	29,892	22.4%	6,669	5.0%
East	8,358	21.7%	2,936	7.6%
Unincorporated County	10,385	19.8%		
Total County	58,787	24.3%	15,959	6.6%

Source: U.S. Bureau of the Census, 1980.

VI. Housing Characteristics

Number and Type of Housing Units

As already noted in a previous section of this report, the housing stock in Contra Costa County is composed predominately of single family homes; an estimated 73% of the housing in the County in January, 1989 was single family homes (see Tables 56 and 57). Only 2% of the housing is provided by mobile homes, located in either mobile home parks and on individual parcels. Multiple family housing (apartments) of two units (duplexes) or more comprises 25% of the housing stock.

Table 56
Number and Percent Distribution of Housing Units by Type of Housing and Sub-Area of the County (as of 1/1/90)

	Single Family(1)	Multiple (2 to 4 Units)	Multiple (5 or more Units)	Mobile Homes	Total
West	59,493	9,601	12,176	1,284	82,554
Central	121,119	9,317	33,513	2,383	166,332
East	42,578	3,892	7,383	2,485	56,338
Total	223,190	22,810	53,072	6,152	314,723
	(70.9)	(7.2)	(16.9)	(2.0)	(100.0)

Source: U.S. Bureau of the Census, 1980; update to 1989 by Contra Costa County Community Development Department

Note: (1) "Single Family" category includes attached homes (condominiums and townhouses).

The distribution of housing types has remained essentially the same since 1980. In 1980, the unincorporated county had a greater percentage of single family units than the cities (85%) as compared to 73%) and a lower percentage of multifamily units (13 versus 25%). East County has slightly more single family and mobile homes, with slightly less than West and Central County.

Table 57
Housing Type Distribution by Sub-Area of County

	Single Family	2-4 Dwelling Units	Multiple (5 or more units)	Mobile Home
West	72.1%	11.6%	14.8%	1.6%
Central	72.8%	5.6%	20.2%	1.4%
East	75.6%	6.9%	13.1%	4.4%
Uninc. Co.	81.2%	5.2%	8.9%	4.6%
Total	70.9%	7.2%	16.9%	2.0%

Source: U.S. Bureau of the Census, 1980; update by Contra Costa County Community Development Department, January 1, 1990.

Housing Tenure

Homeownership has been on a decline since 1980 nationwide, from 65.6% in 1980 to 63.8% in 1988, a reversal of a previous trend of increasing homeownership. The decline has been particularly true for younger households unable to break into the ownership market. According to the National Association of Homebuilders, this is due primarily to a decrease in married households which tend to have high homeownership rates despite an increase in the number of persons in the age groups which are typically home buyers. Other factors discouraging homeownership include high interest rates, low income growth, and tax law changes.

The county's housing stock consisted of 68.3% owner-occupied and 31.7% renter-occupied units in 1980. Tenure within the county has varied historically, although since 1960 it has been relatively steady with approximately seven of every ten households being owner-occupied (Table 58). The percentage of home ownership increased until 1960 when it reached a peak of 72.7% of the households. It has slightly decreased since 1960, partly as a result of an increase in construction of apartment structures during the 1960's, and more recently, due to the high cost of home ownership.

The proportion of renters grew slightly in each of the county sub-markets between 1975 and 1980 (Table 59). The percentage of renters was highest in West County where 36.7% of the housing units were occupied by renters. Central County was the lowest with 29.3% renter households.

Table 58
Percentage of Homes Occupied
by Tenure
(1930-1980)

	% Owner	% Renter
1930	51.3%	48.7%
1940	52.2	47.8
1950	55.3	44.7
1960	72.7	27.3
1970	69.4	30.6
1975	69.3	30.7
1980	68.3	31.7

Source: U.S. Census Bureau; 1975 Special Census of Contra Costa County

Table 59
Percentage of Housing Units Occupied
by Tenure and County Sub-Area
(1975 and 1980)

	1975		1980	
	Owner	Renter	Owner	Renter
West County	66.2%	33.8%	63.3%	36.7%
Central County	71.7	28.2	70.7	29.3
East County	69.6	30.4	68.8	31.2
Unincorporated County	78.1	21.9	75.7	24.3
Total County	69.3	30.7	68.3	31.7

Source: U.S. Bureau of the Census, 1980;
1975 Special Census.

Age of Housing

Physical deterioration of the county's housing stock, in a general sense, is not a severe problem because little of the housing stock is extremely old. However, much of the housing built at the beginning of the growth era will soon reach an age at which deterioration will become a problem. However, high concentrations of physical blight exist in the Country, primarily in the areas of Pittsburg, Richmond and San Pablo. The age of the housing stock varies considerably from area to area (Table 60). In West County, approximately 52% of the housing units was built before 1960, compared to about 27% in East and Central County. Of the county housing existing in January 1990, 45% had been constructed since 1970.

Table 60
Age of Housing
(as of 1/1/90)

	Up to 1960	1960-69	1970-79	1980-89	Total
West	44,401	16,280	11,254	13,067	85,002
	52.2%	19.2%	13.2%	15.4%	100%
Central	46,144	42,509	49,888	30,636	169,177
	27.3	25.1	29.4	18.1	100
East	16,514	7,764	17,027	19,821	61,126
	27.0	12.7	27.8	32.4	100
Total	107,059	66,553	78,169	63,524	315,305
County	34.0	21.7	24.8	20.1	100

Source: U.S. Bureau of the Census; Contra Costa County Community Development Department

Structural Condition

The U.S. Census Bureau in its 1985 Housing Survey found that 1 out of every 8 renters in the Bay Area lived in units with moderate to severe deferred maintenance problems. The California State University Real Estate and Land Use Institute conducted a study on the physical condition of California's housing stock in January of 1987. It estimated that 9% of Contra Costa County's housing stock, or 28,400 units, were in need of rehabilitation (representing repair costs of at least $2,000) or replacement (i.e. repair costs exceeding 50% of the unit's value).

According to a survey conducted by the Contra Costa Redevelopment Agency in 1987, 200 residential structures in the North Richmond Redevelopment area were in need of rehabilitation. An additional 99 residences were in such disrepair that rehabilitation was not financially viable, i.e. the units needed to be replaced. Between 1985 and 1990, 50-55 structures have been publicly or privately abated in the North Richmond area.

The County's 1990 Housing Assistance Plan (based on 1980 Census data) identified 4,537 substandard housing units, 4,082 of which were in need of rehabilitation and 455 of which were in need of replacement. These estimates do not include Antioch, Concord, Richmond and Walnut Creek.

Every year more units become substandard due to age, lack of maintenance, neglect and natural catastrophe (fire, landslide, earthquake, etc.) Several thousand additional homes have suffered earthquake damage in early 1990.

Overcrowding

Overcrowding is defined as households having more than one person per room. According to the results of the 1980 census, in Central County, only 1.3% of the housing stock was considered overcrowded, while in West County 5.0% of all housing units was overcrowded and in East County 4.8% was overcrowded (Table 61). Overcrowding tends to occur at a higher rate in rental housing, with 4.9% of all rental units experiencing overcrowded conditions compared to 2.0% of all owner-occupied housing (Table 62).

Table 61
Overcrowding by County Sub-Area
(Persons Per Room by Number & Percent)
(1980)

Persons per Room	West	%	Central	%	East	%	Total County	%
Less than 1.00	66,088	95.0	131.673	98.7	36,739	95.2	234,500	97.1
1.01 to 1.50	2,383	3.4	1,205	0.9	1,234	3.2	4,822	2.0
1.51+	1,101	1.6	483	0.4	628	1.6	2,212	0.9
Total	69,572	100.0	133,361	100.0	38,601	100.0	241,534	100.0

Source: U.S. Bureau of the Census, 1980

Table 62
Overcrowding by Tenure: Renter vs. Homeowner
(Persons Per Room)
(1980)

	West		Central		East		Total County	
Persons per Room	Renter	Owner	Renter	Owner	Renter	Owner	Renter	Owner
Less than 1.00	92.6%	96.4%	97.6%	99.2%	91.8%	96.7%	95.1%	98.0%
1.01 to 1.50	4.8	2.6	1.5	0.7	4.9	2.4	3.1	1.5
1.51 +	2.6	1.0	0.8	0.2	3.3	0.9	1.8	0.5

Source: U.S. Bureau of the Census, 1980

Vacancy Rates

Vacancy rates are an indicator of the health of the housing market. Overall, for the housing market to operate efficiently, vacancy rates should be at least 5%. Vacancy rates in the county have been significantly below those rates for a number of years (Table 63). Vacancy rates in the County for all units combined ranged from 1.7 to 1.9 from 1981 to 1984 and increased slightly between 1985 amd 1988.

Table 63
Housing Vacancy Rates
by Type and Year

	Single-Family Detached	Single-Family Attached	Multi-Family Units	Total
1985	1.4	3.6	4.1	2.1
1986	1.4	3.8	4.8	2.3
1987	1.4	3.6	5.3	2.6
1988	1.6	4.0	5.4	2.7

Source: Federal Home Loan Bank of San Francisco and U.S. Postal Service. Vacancy rates are for September of each year. FHLB discontinued its Housing Vacancy Surveys in 1988.

1

2 Single family attached units include townhouse and duplex units. Multifamily units include apartment buildings and condominums.

Overpayment

Overpayment for housing occurs when a renter pays more than 30% of the gross household income for housing expenses, including rent, utilities and fuel, or when a homeowner pays over 35% for mortgage payments, homeowner association fees, insurance, taxes, utilities and fuel.

As indicated in Tables 64 and 65, over 40 percent of the county's renters were paying over 30% of their household income for housing expenses in 1980. In comparison, only 13.9%, or 9,760, of county homeowners were paying over 35% of their income for housing at the time of the last census.

Table 64
Proportion of Renters Paying over
30% of Their Total Household Income for Housing
by Income Category
(1980)

	$0 to $4,999	$5,000 to $9,999	$10,000 to $14,999	$15,000 to $19,999	$20,000+	All Renters
West	84.6%	68.5%	34.6%	13.7%	3.2%	40.8%
Central	86.1	85.7	55.0	25.7	6.1	40.0
East	83.9	65.9	32.5	16.9	5.0	43.8
Total County	84.5	75.8	44.5	20.6	5.2	40.8

Source: Estimated from 1980 U.S. Bureau of the Census data.

Table 65
Proportion of Owners Paying over
35% of Their Total Household Income for Housing
by Income Category
(1980)

	$0 to $4,999	$5,000 to $9,999	$10,000 to $14,999	$15,000 to $19,999	$20,000+	All Owners
West	53.9%	27.7%	34.6%	16.9%	3.6%	12.1%
Central	75.0	46.6	33.8	29.0	8.4	14.5
East	60.6	28.3	25.8	25.7	5.5	13.8
Total County	62.1	34.3	26.1	23.8	7.0	13.9

Source: Estimated from 1980 U.S. Bureau of the Census data.

Home Sales Market

While enough vacant land exists in Contra Costa County to provide housing for future generations, many young families and other groups will find it very difficult to purchase these new homes, based upon current sales prices and interest rates. The dilemma of very high housing costs effectively pricing many potential homebuyers out of the market is not peculiar to Contra Costa County, or even the San Francisco Bay Area, but is part of a statewide problem. As of May 1989, the California Association of Realtors (CAR) estimated that Contra Costa County average home prices were $196,242 versus $267,634 Bay Area wide. In November of 1989, CAR estimated the median sales price of a single family detached home in Contra Costa County was $261,908, a 13.6% increase over one year earlier.

There are a number of sources for sales price data. REM Reports presents sales price data from all recorded transactions over a one-week period. Dataman Services data, is based on all recorded transactions over a one-year period, disaggregated by new versus existing home sales. Board of Realtors data includes all sales of properties listed in the Multiple Listing Service (MLS), which excludes many new developments as well as existing homes. A Spear Street Advisors March 1989 study of home sales in Contra Costa County indicates that 26,131 residential properties were sold in 1988, 5,956, or 22.8% of which were new homes. Since Board of Realtors data is based on 9,621 sales in 1988 from properties listed in the Multiple Listing Service, it appears that only a third of all sales are included in the MLS database. Board of Realtors sales price estimates also differ from other data sources in providing average sales prices, rather than median sales prices, which are less skewed by extremely high or low priced sales.

However, Board of Realtors data is useful because of its breakdown into separate categories for detached and attached (townhouses/condominiums) homes. This is important since single family detached homes sell for more than condominiums with similar amenities, so that variations in average sales prices from one community to the next could be a factor of the mix of condominiums versus single family homes, rather than geographic differences in home values. Statewide, CAR estimates that single family homes averaged $210,000 and condominiums/townhomes averaged $151,000, or $189,000 for overall units.

There is a wide range of sales prices of homes in Contra Costa County from one community to the next (see Tables 66 and 67). Based upon the most recent data from local realtors, the most expensive detached single family units are found in the Blackhawk and Diablo areas (with average sales prices of $614,354 and $649,000, respectively) and Alamo (average sales price of $555,836). The only community with average home sales prices below $100,000 are Point Richmond ($92,500) and North and West Richmond ($75,996).

Average condominium sales prices remain available below $100,000 only in Antioch, Concord, Oakley, and Pittsburg with $78,226, $84,889, $80,000 and $94,861 prices respectively. Condominiums/townhomes in the Alamo, Blackhawk, and Orinda areas have average sales prices of over $200,000 ($200,035, $287,767, and $280,050 respectively).

Table 66
Average Residential Sales Prices
by East and Central County Areas
December 1989

	Homes	Townhouses/Condos
Central County		
Alamo	$555,836	$200,035
Blackhawk	614,354	287,767
Clayton	267,312	149,483
Concord	189,362	84,889
Danville	374,295	176,184
Diablo	649,000	N/A
Lafayette	427,793	199,783
Martinez/Pacheco	192,791	116,383
Moraga	440,198	183,108
Orinda	463,125	280,050
Pleasant Hill	231,443	139,818
San Ramon	303,461	154,245
Walnut Creek	312,233	134,430
East County		
Antioch	139,410	78,226
Oakley	149,773	80,000
Pittsburg	116,816	94,861
Brentwood, Knightsen, Bethel Island, Byron	263,911	131,271

Source: Contra Costa Board of Realtors, Statistical Report (Multiple Listing Service)

Table 67
Average Residential Sales Prices in West County
December, 1989

West County	
Crockett	$135,000
Rodeo	165,908
Hercules	182,193
Pinole	161,103
Tara Hills	164,500
Bayview Park	165,000
Montalvin Manor	N/A
El Sobrante	183,125
El Sobrante/Richmond	233,875
Hilltop	130,000
College`	140,333
San Pablo	122,617
North & East Richmond	150,783
Richmond View	179,992
Pt. Richmond	92,500
North & West Richmond	75,996
South Richmond/Balboa	126,333
Bay Front	137,500
Richmond Annex	N/A
El Cerrito	263,150
Combined West County	161,388

Source: West County Board of Realtors

Spear Street Advisors data for 1988 indicated that Alamo, Danville, Lafayette, Moraga and Orinda were the highest priced areas in terms of median sales prices, with El Sobrante, Oakley, Pittsburg, Richmond, and San Pablo as the lowest priced areas (See Table 68).

Table 68
1988 Median Residential Sales Prices
by Contra Costa County Areas
for Resale and New Units

	Resale Units	New Units	Total Units
West County			
El Cerrito	180-189,999	160-169,999*	180-189,999
El Sobrante	110-119,000	Over 250,000*	110-119,999
Hercules	140-149,999	140-149,999	140-149,999
Pinole	130-139,999	150-159,999	140-149,999
Richmond	100-109,999	200-209,999	110-119,999
Rodeo	120-129,999	220-229,999*	120-129,999
San Pablo	90-99,999	130-139,999*	90-99,999
Central County			
Alamo	Over $250,000	Over $250,000	Over $250,000
Clayton	200-209,999	Over 250,000	210-219,999
Concord	130-139,999	200-209,999	130-139,999
Danville	Over 250,000	Over 250,000	Over 250,000
Lafayette	Over 250,000	240-249,999	Over 250,000
Martinez	120-129,999	170-179,999	130-139,999
Moraga	Over 250,000	Over 250,000	Over 250,000
Orinda	Over 250,000	Over 250,000	Over 250,000
Pleasant Hill	140-149,999	220-229,999	160-169,999
San Ramon	210-219,999	Over 250,000	230-239,999
Walnut Creek	180-189,999	170-179,999	180-189,999
East County			
Antioch	100-109,999	140-149,999	120-129,999
Brentwood	120-129,999	130-139,999	130-139,999
Byron	210-219,999	180-189,999	200-209,999
Oakley	100-109,999	120-129,999	110-119,999
Pittsburg	90-99,999	120-129,999	100-109,999
Total County	140-149,999	170-179,999	140-149,999

Source: Dataman Information Services Inc., Spear Street Advisors, Inc. (included in Feasibility Report for 1989 Contra Costa County Home Mortgage Revenue Bonds)
* Numbers may not be representative due to small sample size.

County-wide median sales prices from Spear Street Advisors for 1988 were approximately $140,000 for resale units, $170,000 for new units and $150,000 for new and resale units combined (see Table 69). Resale units sold for an average of 18% less than new units. More significant, however, is that a significant portion of resale units were available at prices below $100,000 - 27% of resale units as compared to only 6% of new units. At the other extreme, a third of all new units sold for over $200,000 in 1988. Affordable homeownership opportunities for low income households without any public subsidies appear to be supplied exclusively by the resale market.

Table 69

Distribution of Home Sales Prices for Resale and New Units
Contra Costa County
(1988)

	Resale Housing			New Housing			Totals		
Price Categories	Number of Units	Percent of Total	Cumulative Percent	Number of Units	Percent of Total	Cumulative Percent	Number of Units	Percent of Total	Cumulative Percent
Below $50,000	1,971	9.77%	9.77%	4	0.07%	0.07%	1,975	7.56%	7.56%
50,000 - 59,000	438	2.17%	12.94%	12	0.02%	0.27%	450	1.72%	9.28%
60,000 - 69,000	603	2.99%	14.93%	21	0.35%	0.62%	624	2.39%	11.67%
70,000 - 79,000	681	3.38%	18.30%	69	1.16%	1.78%	750	2.87%	14.54%
80,000 - 89,000	840	4.16%	22.47%	91	1.53%	3.31%	931	3.56%	18.10%
90,000 - 99,000	961	4.76%	27.23%	166	2.79%	6.09%	1,127	4.31%	22.41%
100,000 - 109,000	1,160	5.75%	32.98%	257	4.31%	10.41%	1,417	5.42%	27.84%
110,000 - 119,999	1,188	5.89%	38.87%	381	6.40%	16.81%	1,546	6.00%	33.84%
120,000 - 129,000	1,142	5.66%	44.53%	511	8.58%	25.39%	1,653	6.33%	40.17%
130,000 - 139,000	1,077	5.34%	49.87%	445	7.47%	32.86%	1,522	5.82%	45.99%
140,000 - 149,000	867	4.30%	54.17%	393	6.60%	39.46%	1,260	4.82%	50.81%
150,000 - 159,000	761	3.77%	57.94%	263	4.42%	43.87%	1,024	3.92%	54.73%
160,000 - 169,000	746	3.70%	61.64%	286	4.80%	48.67%	1,032	3.95%	58.68%
170,000 - 179,000	703	3.48%	65.12%	290	4.87%	53.54%	993	3.80%	62.48%
180,000 - 189,000	659	3.27%	68.39%	236	3.96%	57.51%	895	3.43%	65.91%
190,000 - 199,000	489	2.42%	70.81%	286	4.80%	62.31%	775	2.97%	68.87%
100,000 - 109,000	437	2.17%	72.98%	228	3.83%	66.13%	665	2.54%	71.42%
210,000 - 219,000	451	2.24%	75.21%	226	3.79%	69.93%	677	2.59%	74.01%
220,000 - 229,000	440	2.18%	77.39%	232	3.90%	73.28%	672	2.57%	76.58%
230,000 - 239,000	368	1.82%	79.22%	216	3.63%	77.45%	584	2.23%	78.81%
240,000 - 249,000	321	1.59%	80.81%	168	2.82%	80.27%	489	1.87%	80.69%
250,000 and over	3,872	19.19%	100.00%	1,175	19.73%	100.00%	5,047	19.31%	100.00%
	20,175	100.00%		5,956	100.00%		26,131	100.00%	

Source: Dataman Information Service Inc.; Spear Street Advisors, Inc.

Spear Street Advisors data for 1988 shows the most overall sales activity in Antioch, Concord, Danville, Richmond, Walnut Creek (see Table 70). The most sales activity for existing homes occurred in Antioch, Concord, Danville, Martinez, Pittsburg, Richmond, San Ramon, and Walnut Creek. The most sales activity for new development in 1988 occurred in Antioch, Danville, Hercules, and San Ramon.

Table 70
1988 Number of Residential Sales by Sub-Areas of the County for Resale and New Units

	Resale Units	New Units	Total
West County	3,762		
El Cerrito	402	5	407
El Sobrante	118	2	120
Hercules	464	591	1,055
Pinole	375	142	517
Richmond	1,918	462	2,380
Rodeo	146	2	148
San Pablo	339	8	347
Central County	11,661		
Alamo	331	48	379
Clayton	230	31	261
Concord	2,956	453	3,409
Danville	1,618	679	2,297
Lafayette	690	58	748
Martinez	1,157	184	1,341
Moraga	441	45	486
Orinda	523	17	540
Pleasant Hill	484	198	682
San Ramon	1,111	563	1,674
Walnut Creek	2,120	444	2,564
East County	3,162		
Antioch	1,155	784	1,939
Brentwood	202	140	342
Byron	282	201	483
Oakley	358	459	817
Pittsburg	1,165	234	1,399
Total County	20,175	5,956	26,131

Source: Spear Street Advisors, Inc., 1988 Housing Purchase Price Data for Contra Costa County, March 15, 1989

Appreciation in home values in the San Francisco Bay Area hit record levels in early 1988. The California Association of Realtors estimated that home prices in California rose 19.7% from 1988 to 1989 and in the region rose by an average of 24.8% during this same period. A San Francisco Examiner-Caldwell Banker survey estimated appreciation rates by tracing home values in Bay Area neighborhoods over a one-year period (See Table 72). In Contra Costa County, the greater increase in condominium sales prices occurred in Moraga and Pleasant Hill, where values escalated dramatically 44.5% and 47.0% from 1988 to 1989. At the other extreme, Antioch showed a decline in condominium sales prices of 7.2% over the same period and Concord realized zero appreciation. All of the communities surveyed in Contra Costa County had very high appreciation rates in detached single family homes with the exception of Martinez. According to the West County Board of Realtors, West County average sale prices have increased 83% in the five year period from December, 1984 to December, 1989.

Some of the appreciation in home values can be attributed to increases in amenities package provided in single-family homes. Size in particular has been somewhat contingent on the health of the economy; as interest rates have made housing more affordable, housing sizes have increased. New single-family homes have increasingly included second stories, garages, 2 or more bathrooms, and fireplaces.

More importantly, though, the double digit appreciation rates in home sales reflect a very tight housing market with demand far exceeding supply. One indicator of this is the amount of unsold inventory of homes on the market which the CAR reports hit its lowest level since 1982 in August 1988. However, while increased unit sizes partially explain increased sales prices, local statistics from the Construction Industry Research Board indicate that housing values for new homes have escalated in Contra Costa County between 1981 and 1989, even on a cost per square foot basis.

Table 71
Single Family Residential Appreciation Rates
1984 -1989
Contra Costa County

	West County	South Central	East County	Bay Area & Region
October '84 - October, '85	2.8	3.2	3.3	5.5
October '85 - October, '86	7.5	5.3	6.5	9.9
October '86 - October, '87	5.1	9.3	9.1	11.1
October '87 - October, '88	12.2	13.8	7.3	18.9
October '88 - October, '89	25.3	21.9	18.5	24.3
Cumulative October, '84 - October, '89	63.3	64.8	52.4	90.4

Source: Real Estate Research Council of Northern California, Northern California Real Estate Report, February, 1990.

West County sample included homes tracked in Richmond, Martinez, El Cerrito, and Pinole. South Central included Orinda, Moraga, Pleasant Hill, Walnut Creek, Alamo, Lafayette, Danville, and Concord. East County included Concord, Pittsburg, and Antioch.

Table 72
Appreciation in Home Values in Contra Costa County
August, 1988 - August, 1989

	Condominium			Single-family Residence		
	1988	1989	% Change	1988	1989	% Change
Alamo	$176,500	$184,950	4.8%	$325,000	$425,000	30.8%
Antioch	97,000	90,000	-7.2%	126,000	145,000	15.1%
Blackhawk	279,000	289,000	3.5%	405,000	474,000	17.0%
Clayton	119,500	136,500	14.2%	213,000	250,000	17.4%
Concord	90,000	90,000	0%	172,500	210,000	21.7%
Danville	172,500	215,000	24.6%	274,950	330,000	20.0%
Diablo	N.A.	N.A.	N.A.%	420,000	500,000	19.0%
El Cerrito	N.A.	N.A.	N.A.%	220,300	265,000	20.3%
Kensington	N.A.	N.A.	N.A.%	275,000	329,000	19.7%
Lafayette	175,000	220,000	25.8%	275,000	350,000	27.3%
Martinez	107,500	109,000	1.4%	187,500	200,000	6.7%
Moraga	119,000	175,000	47.0%	275,000	340,000	23.6%
Orinda	375,000	398,000	6.1%	300,000	398,250	32.8%
Pittsburg	78,000	87,000	14.1%	125,000	145,000	16.0%
Pleasant Hill	128,000	185,000	44.5%	177,600	230,000	29.5%
San Ramon	140,000	162,000	15.7%	187,000	245,000	31.0%
Walnut Creek	159,000	178,500	12.3%	230,000	283,000	27.4%
Richmond View	N.A.	N.A.	N.A.%	177,000	229,000	29.4%

Source: San Francisco Examiner - Caldwell Banker Residential Real Estate Survey

Homeownership Affordability

Affordability in homeownership is a function of sales price levels, household income levels, lender underwriting standards, and home mortgage interest rates.

Table 73
Bay Area Housing Affordability

	1980	1989	% Change
Median Household Income	$ 20,608	$ 34,496	67.4
Median Sales Price (Single Family Detached)	$110,163	$260,592	136.5
Average Mortgage Rate	13.11%	10.60	-19.1
Income Required to Buy	$ 40,657	$ 85,661	110.7
Percent Able to Afford	14.2%	11%	-22.5

Sources: Urban Decision Systems, California Association of Realtors, Federal Home Loan Bank Board, Bay Area Council

As Table 73 indicates, only 11% of Bay Area households could afford the median priced single family detached home in 1989, assuming a 20% downpayment and a 30 year fixed rate mortgage. While median household incomes have increased only 67% since 1980 and sales prices of single family homes have escalated 136% in that time period, affordability has declined despite lower mortgage interest rates. The fact remains that a very high income level of over $85,000 per year is required to purchase the median priced single family home in the Bay Area.

Table 74
Mortgage Interest Rates

	Fixed Rate Loans (1)	Adjustable Rate Loans (2)	Tax Exempt Bond Financed Loans (3)
1980	13.77	N/A	9.70
1981	16.64	N/A	12.39
1982	16.09	N/A	12.48
1983	13.23	N/A	10.03
1984	13.87	12.35	10.65
1985	12.42	11.02	9.68
1986	10.18	9.45	8.04
1987	10.20	8.69	8.15
1988	10.33	8.93	8.12
1989	10.32	N/A	7.74

(1) Federal Home Loan Mortage Corporation. Survey of major lenders, rates on fixed rate, 80% loan to value mortgages.
(2) Federal Home Loan Bank Board. Effective rates of 75% loan to value ARM's (including amortized value of points).
(3) Smith Barney, "Credit Market Comment"

Source: Published in National Association of Home Builders, The Current Housing Situation

Interest rates have the greatest impact on home sales price affordability. Table 74 indicates changes in interest rates for fixed rate, adjustable rate, and tax exempt bond financed mortgage loans over the last decade. Adjustable rate financing provides fluctuating mortgage payments with initially lower rates tied to an interest rate established by an economic indicator with a cap on the maximum interest rate; while tax exempt bond financing provides below market rate fixed rate loans with low mortgage payments for the life of the loan.

Based on the California Association of Realtors estimate of $261,908 for the median priced single family home in Contra Costa County in November of 1989, Contra Costa County households would need an annual income of $95,857, assuming a 10% down payment of $26,190, a 10% 30-year fixed rate mortgage, taxes and insurance at 1.5% of the sales price, and housing costs at 30% of income. Obviously, these prices are far beyond the reach of most Contra Costa County households.

Given the current lending practices of banks and saving and loans, to qualify for a loan to purchase the average priced $200,000 home in Contra Costa County, the buyer would need an annual income of approximately $73,000, assuming a 10% down payment (see Table 75). In order to qualify for a much less expensive $100,000 home, the buyer would be required to have an income of over $36,000. On the other end of the spectrum, to afford payments for a $300,000 house, the buyer would need a combined income of over $9,000 per month, or almost $110,000 annually.

Table 75
Home Sales Price and Household Income Required

		Gross Household Income Needed to Qualify for a Loan	
Homes Sales Price	Downpayment	Monthly	Annual
$ 80,000	$ 8,000	$2,440	$ 29,280
$100,000	10,000	3,049	36,593
$120,000	12,000	3,659	43,910
$140,000	14,000	4,269	51,230
$160,000	16,000	4,879	58,547
$180,000	8,000	5,489	65,867
$200,000	20,000	6,099	73,187
$250,000	25,000	7,623	91,480
$300,000	30,000	9,148	109,777

Source: Contra Costa County Community Development Department

Note: Assumes 10% down payment; 90% of sales price is amortized over 30 years at 10.0% interest rate; annual costs of property tax and insurance is 1.5% of sales price; monthly housing costs are 30% of gross family income. Calculations have been rounded off.

With a larger downpayment or alternative forms of financing, such as adjustable rate mortgage or mortgage revenue bond financing, monthly housing costs, and consequently the required income to qualify for a loan, would drop.

Table 76 illustrates that a two point difference in mortgage interest rates, or the difference between an 8% and a 10% interest rate, has more impact on monthly mortgage payment levels than a $10,000 difference in the mortgage level based on a higher or lower downpayment amount. Likewise, in the example of a $100,000 sales price, a $10,000 difference in sales price would have the same impact on monthly mortgage payments as a $10,000 difference in downpayment.

Table 76
Impact of Down Payment and Mortgage Interest Rates on Monthly Mortgage Payments

	Mortgage Interest Rate		
Downpayment	8%	10%	12%
10%	$660	$790	$926
20%	$587	$702	$823

Source: Contra Costa County Community Development Department

Assumes 30 year fixed rate mortgage on $100,000 home.

The shortage of affordable housing has larger planning implications. As areas of the County fail to provide housing affordable to all income ranges, particularly for very low and low income households, these populations are forced to commute farther and farther distances between affordable housing and employment centers. The lack of affordable housing has direct negative impacts on transportation, air quality, and energy conservation/efficiency.

Rental Market

The rental market has changed significantly since 1985. At that time, the housing market was extremely tight with low vacancy rates at 1% or less in the Bay Area. The Contra Costa County rental market is continuing to recover from the oversupply resulting from the high level of production in 1986. This peak production level can be attributed to several factors: moderate interest rates, availability of tax exempt bond financing, rising rents, and a switch in builder/lending industries away from overbuilt office and commercial development. Previously high interest rate levels of almost 17% in 1982 had dropped to 12-13% in 1985 and have continued to decline since then. According to a 1985 Bay Area Council study, bond financing was the single most important factor fostering rental housing production in the Bay Area.

Table 77
1989 County-wide Median Rent Levels

		Unit Sizes			
	Rooms	Studio	1 Bedroom	2 Bedroom	3+ Bedroom
Apts.		$466 (22)	$480 (125)	$575 (180)	$750 (19)
Condos		- (0)	580 (28)	750 (85)	1000 (36)
Houses		415 (5)	510 (10)	700 (45)	980 (343)
Total	$350 (113)	460 (27)	510 (163)	625 (310)	975 (398)

Note: Numbers in ()'s = sample size

Source: Community Development Department. Rent listings for unfurnished apartments, condominiums, and houses from 7/23/89 in the Antioch/ Pittsburg Daily Ledger, Contra Costa Times, and West County Times. (Duplexes are included in the apartment category.) Shared housing listings for rooms for rent from November 18 or 19, 1989 in West County Times, Contra Costa Times, and Daily Ledger.

As Table 77 indicates, condominiums tend to be slightly more expensive than houses, while houses are generally significantly more expensive than apartments with comparable number of bedrooms. The higher prices for condominiums can be attributed to the amenity packages (such as swimming pools, spas, and tennis courts) included in condominium rentals and the tendency to be newer and, therefore, higher priced units.

A breakdown of 1989 median rent levels by the three sub-areas of the County (West, Central, and East), presented in Table 78, reveals that East County has the lowest rent levels in all unit sizes (with the exception of studio apartments for which there were very few listings). Central County had the most expensive median levels.

A more detailed breakdown of 1989 median rents for communities within the three sub-areas reveals pockets of affordability (see Table 79). The least expensive rentals in the County appear to be located in West County in Crockett/Rodeo, Richmond, and San Pablo and in East County in Antioch, Pittsburg, and Oakley. The most expensive communities for renters are all in the Central County, except for Discovery Bay in East County. The high cost Central County communities include Alamo, Clayton, Danville, Lafayette, Moraga, Orinda, San Ramon, and Walnut Creek.

Table 78
1989 Median Rent Levels by Sub-Areas of the County

	Unit Sizes				
	Rooms	Studio	1 Bedroom	2 Bedroom	3+ Bedroom
West County					
Apts.		$325 (7)	$475 (36)	$598 (62)	$750 (7)
Condos		- (0)	675 (2)	713 (14)	- (0)
Houses		- (0)	495 (4)	688 (18)	950 (49)
Sub Total	$337 (20)	$325 (7)	$475 (42)	$625 (94)	$925 (56)
Central County					
Apts.		$500 (12)	$523 (70)	$615 (77)	$1300 (7)
Condos		- (0)	575 (25)	775 (67)	1000 (32)
Houses		415 (5)	550 (5)	795 (15)	1200 (207)
Sub Total	$350 (82)	$500 (17)	$543 (100)	$665 (159)	$1190 (246)
East County					
Apts.		$395 (3)	$435 (19)	$495 (41)	$725 (5)
Condos		- (0)	550 (1)	612 (4)	695 (4)
Houses		- (0)	385 (1)	687 (12)	875 (87)
Sub Total	$322 (11)	$395 (3)	$435 (21)	$510 (57)	$850 (96)

Note: Numbers in ()'s = sample sizes

Source: Community Development Department. Rental listings (unfurnished) for 7/23/89 in Antioch/Pittsburg Daily Ledger, Contra Costa Times, West Contra Costa Times. Room listings from November 18 or 19, 1989 in Daily Ledger, Contra Costa Times, and West Contra Costa Times.

Table 79
1989 Median Rents by Community

	Unit Sizes			
	Studio	1 Bedroom	2 Bedroom	3+ Bedroom
West County				
Crockett/Rodeo	$450 (2)	$512 (6)	$565 (5)	$ 850 (5)
El Cerrito	- (0)	550 (1)	750 (3)	975 (4)
El Sobrante	- (0)	525 (1)	610 (16)	1125 (4)
Hercules	- (0)	- (0)	712 (4)	1050 (11)
Pinole	- (0)	512 (2)	700 (4)	1050 (6)
Richmond	325 (5)	480 (25)	625 (37)	870 (15)
San Pablo	- (0)	470 (6)	550 (25)	900 (11)
Central County				
Alamo	- (0)	- (0)	- (0)	1690 (5)
Clayton	- (0)	- (0)	850 (1)	1275 (2)
Clyde	- (0)	- (0)	- (0)	825 (1)
Concord	460 (7)	525 (39)	620 (71)	950 (62)
Danville	550 (1)	- (0)	803 (6)	1450 (25)
Lafayette	475 (1)	595 (6)	850 (7)	1350 (14)
Martinez	445 (2)	450 (16)	708 (16)	1095 (21)
Moraga	- (0)	- (0)	950 (3)	1500 (8)
Orinda	535 (1)	763 (2)	- (0)	1350 (16)
Pleasant Hill	- (0)	568 (8)	680 (8)	1050 (28)
San Ramon	- (0)	- (0)	800 (5)	1200 (20)
Walnut Creek	515 (5)	565 (29)	750 (42)	1250 (41)
West County				
Antioch	- (0)	435 (15)	500 (36)	880 (58)
Brentwood	- (0)	- (0)	660 (2)	700 (1)
Discovery Bay	- (0)	- (0)	850 (2)	1175 (5)
Oakley	- (0)	- (0)	- (0)	850 (21)
Pittsburg	395 (1)	400 (3)	550 (16)	825 (34)

Source: Community Development Department. Rental listings (unfurnished) for 7/23/89 in Antioch/Pittsburg Daily Ledger, Contra Costa Times, West Contra Costa Times.

Rental Affordability

Based on 1989 countywide median rent levels, Contra Costa County households would need a very low income level of $14,000 for shared housing, a low income level of $18,400 for studio units, a low income level of $20,400 for one bedroom units, and $25,000 for two bedroom units and a moderate income level of $39,000 for three or more bedroom units, as defined by 1989 HUD median income levels adjusted by household size.

Median rent levels were affordable to very low income households only in certain communities. For very low income households, median rents levels for studios were only affordable in Richmond, for one bedrooms in Martinez and East County, and for two bedrooms in Antioch. Median rent levels for three or more bedroom units were not affordable to very low income households in any area of the County. Rooms to share were only affordable to those in the upper range of th every low income category.

Countywide median rent levels for studios, one bedrooms, and two bedrooms fell approximately in the middle of the rents affordable to low income households. East County was the only area of the County that had median rents in one and two bedroom units affordable to all low income households. Median rents were not affordable to low income households in the three or more bedroom unit size in any of the three areas of the County.

Based on HUD 1989•median income levels for Contra Costa County, moderate income households could afford median 1989 rents, with the exception of the larger 3 or more bedroom units in affordable to the lower range of moderate income households in West and Central County.

In conclusion, it appears that the private sector is providing rentals affordable to moderate income households and to smaller low income households in the upper low income range in all unit sizes. For very low income households, the lower income range of low income households, and large low income households (four or more persons), the private sector is not providing affordable rental units in the three sub-areas of the County. The most critical needs for housing to be assisted through public programs to provide affordable rent levels are for shared housing for very low income households, for rentals affordable to very low income and the lower end of the low income range throughout the County, and for 3 or more bedroom rentals affordable to low income households.

It is important to note that HUD median income levels are based on income levels for a family of four and then adjusted for different household sizes. Family incomes, at $26,510 in the 1980 census, averaged 16% higher than household incomes, of $22,870. Incomes are also much lower for renter households than for households or families overall. Average renter incomes in the 1980 census of $13,866 were only 52% of average family incomes of $26,510 in Contra Costa County. Since homeowner and family incomes tend to be higher than incomes for renter households of the same size, HUD income figures tend to be high. This means that the affordability problem is much more severe that suggested by HUD income levels.

Table 80
Affordable Rent Levels For Very Low, Low, and Moderate Income Family Households In 1989

Maximum Income Level	Unit Types: Studio	1 Bedroom	2 Bedrooms	3+ Bedrooms
Very Low	$ 394	$ 450	$ 506	$ 563
Low	594	676	762	848
Moderate	891	1,017	1,143	1,272

Based on U.S. Department of Housing and Urban Development median income levels for Oakland PMSA (Alameda and Contra Costa Counties) as of February, 1989. Very low income is defined as 50% of median income levels adjusted by household size (adjusted by HUD to match State Median Income Levels), low income as 80% of median income, and moderate at 120% of median income. Affordable rent levels are based on 30% of monthly household income for the following household sizes:

Studio -- one person household
One Bedroom -- two person household
Two Bedroom -- three person household
Three Bedroom -- four person household

Table 81
Affordable Rent Levels for Very Low, and Moderate Income Renter Households in 1989

Maximum Income Level	Unit Types			
	Studio	1 Bedroom	2 Bedrooms	3+ Bedrooms
Very Low	$ 197	$ 225	$ 253	$ 282
Low	297	338	381	424
Moderate	446	509	572	636

NOTE: Based on U.S. Department of Housing and Urban Development median income levels for Oakland PMSA (Alameda and Contra Costa Counties) as of February, 1989. Very low income is defined as 50% of median income levels adjusted by household size (adjusted by HUD to match State Median Income Levels), low income as 80% of median income, and moderate at 120% of median income. Affordable rent levels are based on 30% of monthly household income for the following households sizes:

Studio - one person household
One Bedroom - two person household
Two bedroom - three person household
Three bedroom - four person household

Source: U.S. Department of Housing and Urban Development, February, 1989; HUD family incomes adjusted by Community Development Department by .5 factor for renter vs. family income levels from 1980 U.S. Bureau of Census income data.

When HUD income levels are adjusted for rent levels affordable to the renter population alone, by a factor of 50%, countywide median rents are not affordable to even moderate income renter households. By sub-area of the County, only studios and one bedrooms in West and East County and two bedrooms in East County are affordable to some moderate income renter households. By sub-area and by community, no median rent levels were affordable to very low or low income renter households (see Table 81).

APPENDIX B

SUMMARY OF FEDERAL AND STATE LOW AND MODERATE INCOME PROGRAMS

APPENDIX B

FEDERAL AND STATE LOW AND MODERATE INCOME PROGRAMS - A SELECTED SUMMARY

Name of Program	Administering Agency and Intermediaries	Eligible Use of Funds	Target Population
	RENTERS		
Section 202: Direct loan for housing for the elderly and handicapped	Admin: HUD Int: Private non-profit developers or cooperatives	Loans to construct or acquire and rehabilitate rental or cooperative housing	Households with elderly (62+) or handicapped
Section 8: Low-income rent assistance (existing housing)	Admin: HUD Int: Public housing agency	Recurring grant for payment of part of rent to contract units selected by participating households	Very-low income households
Housing Vouchers	Admin: HUD Int: Local Housing Authorities	Recurring monthly assistance payment based on difference between tenants contribution toward rent and a payment standard	Very-low income renters
Section 17: Rental Rehabilitation Program	Admin: HUD Int: State and local governments	Grants to state and local government to rehabilitate rental units with vouchers or Sect. 8 rental assistance	Very-low income renters
Section 17: Housing Development Grants (HODAG)	Admin: HUD Int: HUD-designated cities, urban counties, and states or designated sub-parts	Grants to local government to construct or substantially rehabilitate rental or limited equity cooperative housing	Very-low and low income renters in federally designated high need areas or HUD-approved special housing purposes
Public Housing	Admin: Local Housing Authorities	Loans to construct and rehabilitate multi-unit rental housing	Very-low income households

Name of Program	Administering Agency and Intermediaries	Eligible Use of Funds	Target Population
		RENTERS - Cont.	
Public Housing Operating Subsidies and Debt Service	Admin: HUD Int: Local Housing Authorities	Recurring grant to pay operating costs, and principal and interest on bonds	Very-low income households
Comprehensive Improvement Assistance Program	Admin: HUD Int: Housing Authorities	Loans for capital improvements and repairs to public housing projects	Very-low income households
Section 8 Loan Management Set-Aside and Property Disposition	Admin: HUD Int: Local Housing Authorities, non-profit and private developers	Subsidies to financially troubled and converted units based on difference between tenants contribution toward rent and unit rental amount	Low income households
Section 8 Moderate Rehabilitation	Admin: HUD Int: Public housing agencies, for-profit and non-profit organizations, private owners, state housing finance agencies	15 year subsidies to households living in units which have been rehabilitated	Very-low income households
Section 106(b) - Non-Profit Sponsor Assistance Program	Admin: HUD Int: Non-profit corporations	Loans to sponsors of Section 202 housing for seed money and pre-construction expenses	Elderly and handicapped households
Section 207 - Mortgage Insurance -- Rental Housing	Admin: HUD Int: Investors, builders, developers, and others who meet HUD requirements for mortgagors	Insures mortgages for the construction or rehabilitation of dwellings with five or more units	Low and moderate income households

Name of Program	Administering Agency and Intermediaries	Eligible Use of Funds	Target Population
		RENTERS - Cont.	
Section 213 - Mortgage Insurance -- Financing Cooperative Housing Projects	Admin: HUD Int: Non-profit organizations and other corporations who intend to sell the project to a non-profit organization	Insures mortgages for the construction or rehabilitation of fire or more units of cooperative housing	Low and moderate income households
Section 220 - Mortgage Insurance -- Rental Housing in Urban Renewal Areas	Admin: HUD Int: Investors, builders, developers, public bodies, and others who met HUD requirements for mortgagors	Insures lenders against loss on mortgages for acquiring or rehabilitating rental housing in urban renewal areas	Low and moderate income households
Section 231 - Mortgage Insurance -- Rental Housing for the Elderly	Admin: HUD Int: Investors, builders, developers, public bodies and non-profit sponsors	Insures lenders against loss on mortgages for constructing or substantially rehabilitating unsubsidized rental housing	Elderly and handicapped households
GNMA Mortgage (tandem plan)	Admin: GNMA Int: Private lenders and developers	Loans to construct units	Currently low-income households
Section 515: Rural Rental Housing Program	Admin: FmHA Int: Public agencies and private limited profit and non-profit developers	Loans to construct or substantially rehabilitate rental and cooperative housing	Rural, low- and moderate-income families and elderly or handicapped.

Name of Program	Administering Agency and Intermediaries	Eligible Use of Funds	Target Population
	RENTERS - Cont.		
Section 514: Farm Labor Housing Loans	Admin: FmHA Int: Public agencies and private non-profit developers	~~Low interest~~ Loans to construct, rehabilitate or acquire rental housing	Farmworkers
Section 516: Farm Labor Housing Grants	Admin: FmHA Int: Public agencies and private non-profit developers	Non-recurring grants to construct, rehabilitate or acquire rental housing	Farmworkers
Section 521: Rental Assistance Program	Admin: FmHA Int: Public agencies and non-profit organizations	Recurring grant for payment of part of rent in FmHA-financed rental units	Very-low and low-income rural households and elderly
CHFA Multi-Family Rehabilitation and Infill New Construction Program	Admin: CHFA Int: Local governments non-profit and private developers	Loans to construct, rehabilitate or acquire rental property	Low income households
CHFA Rental Housing Mortgage Loan Program	Admin: CHFA Int: Limited profit developers, non-profit sponsors, local housing agencies	Loans to construct or rehabilitate rental units	Very low and low persons and families
Rental Housing Finance Program	Admin: CHFA Int:	Secondary financing to buy down rent levels	Very low and low income households

Name of Program	Administering Agency and Intermediaries	Eligible Use of Funds	Target Population
		RENTERS - Cont.	
Special User Housing Rehabilitation Program	Admin: HCD Int: Local government, for profit and non-profit organizations	Low interest loans to aquire and/or rehabilitate substandard apartments, group residences, and residential hotels occupied by special populations	Elderly, mentally disabled, and physically disabled, low- and very-low income households
Rental Housing Construction Program	Admin: HCD Int: Local Housing Authorities, local government, private, non-profit agencies, CHFA	Direct loans and operating subsidies to construct multi-family rental developments	Very-low and low-income households
Rural Rental Assistance (Component of Rental Housing Construction Program)	Admin: HCD Int:	Operating subsidies to FmHA Section 515 financed projects	Very-low and low income rural households
Migrant Services Program Construction	Admin: HCD Int: None	Non-recurring grants to construct and rehabilitate migrant farmworker centers	Seasonal farmworkers
Housing Assistance Program	Admin: HCD Int: Housing Authorities	Section 8 certificates	Developmentally, mentally, and physically disabled adults and low income individual households not able to live independently
Family Housing Demonstration Program	Admin: HCD Int:	Construction or acquisition/rehabilitation of housing which includes child care, jobtraining, and employment services	Low income households

Name of Program	Administering Agency and Intermediaries	Eligible Use of Funds	Target Population
	RENTERS - Cont.		
Low Income Housing Tax Credits (State and Federal)	Admin: MBTCAC Int: For-profit and non-profit developers or rental property owners	Tax credits for acquisition, rehabilitation and construction of rental housing	Very low and low income households (up to 60% of area median income)
Calif. Disaster Rehabilitation	Admin: HCD Int: Individuals or local government	Loans to acquire and rehabilitate rental properties; relocation assistance to displaced persons	October, 89 Earthquake victims
Tax Exempt Multi-family Mortgage Revenue Bonds	Admin: Cities and Counties with authority from state Int: Private lenders/ credit enhancers and private or non-profit developers	Loans to construct or rehabilitate and acquire rental housing	Low income renters
	OWNERS		
Section 235: Homeownership Assistance for Low- and Moderate-Income Families	Admin: HUD Int: Private lenders	Recurring grant for payment of part of interest to finance new or substantially rehabilitated owner-occupied units	Low- and moderate income households
Section 203(b) - FHA Mortage Insurance - Homes	Admin: HUD/FHA Int: All families	Insures lenders against loss on mortgage loans	Low- and moderate-income households

Name of Program	Administering Agency and Intermediaries	Eligible Use of Funds	Target Population
	OWNERS - Cont.		
Section 220 - Mortgage Insurance -- Homes in Urban Renewal Areas	Admin: HUD/FHA Int: Investors, builders, developers, public bodies and others who meet HUD requirements for mortgages	Insures lenders against loss on mortgages for acquiring and rehabilitating one to eleven-unit housing in urban renewal areas	Low- and moderate-income households
Section 221(d)(2) Homeownership Assistance to Low and Moderate Families	Admin: HUD/FHA Int:	Loans to purchase, construct, or rehabilitate 1-4 unit dwellings	Low and moderate families
Nehemiah Grant Program	Admin: HUD Int: Non-profit corporations	Deferred payment 2nd loans to homeowners to purchase newly constructed or rehabilitated HUD-approved units	Median income households
VA Loan Guaranty Program	Admin: DVA Int:	Loan guarantees for loans made to veterans by private lenders	Qualified veterans
Section 502: Homeownership and Rehabilitation Loans	Admin: FmHA Int: None	Loans to buy, build, repair, or renovate homes owner occupied	Rural very low and low-income homeowners
FmHA Section 533 - Rural Housing Preservation Grants	Admin: FmHA Int: Governmental entities and non-profit organizations	Grants or loans to repair and rehabilitate homes to remedy code violations	Very low- and low-income rural homeowners
Section 504: Home Repair Loans or Grants	Admin: FmHA Int: None	Loans or non-recurring grants to repair owner-occupied units with safety or health hazards	Rural, very-low income homeowners

Name of Program	Administering Agency and Intermediaries	Eligible Use of Funds	Target Population
	OWNERS - Cont.		
Section 523: Self-Help Housing Site Loans	Admin: FmHA Int: Public and non-profit groups	Technial assistance grants for self-help projects funded under 502 program	Rural, very-low and low income homeowners who are building their own homes
Matching Downpayment Program	Admin: CHFA Int:	Matching downpayment contributions for CHFA mortgage loans	Low income households
CHFA Home Mortgage Purchase Program	Admin: CHFA Int: Private lenders and local governments	Loans to purchase or improve owner-occupied single-family units and one-to-four unit buildings	Low- and moderate-income households in mortgage assistance areas and concentrated rehabilitation areas
Self-Help Housing Program	Admin: CHFA Int: Non-profit developers	Mortgage loans and construction loan credit enhancers for self-help housing	Low income families
California Veterans Farm and Home Loan Program (CAL-VET)	Admin: DVA Int: None	Loans to purchase and improve owner-occupied single-family homes and mobilehomes	California veterans
California Self-Help Housing Program	Admin: HCD Int: Local governments and non-profit organizations	Mortgage assistance or technical assistance grants for constructing or rehabilitating homes	Low- and moderate-income households
Mobilehome Park Assistance Program	Admin: HCD Int: Mobilehome residents and local public entity as co-applicant	Loans and technical assistance to mobilehome park residents to purchase and operate mobilehome parks	Low-income households

Name of Program	Administering Agency and Intermediaries	Eligible Use of Funds	Target Population
		OWNERS - Cont.	
California Homeownership Assistance Program (CHAP)	Admin: HCD Int: Local government agencies	Loans to purchase condominiums, mobilehome park spaces, mobilehomes on permanent foundation, and cooperative units	Low- and median income first-time homebuyers and condominium conversion displaces
California Disaster Rehabilitation Program	Admin: HCD Int: Individuals or local government	Loans to homeowners of owner-occupied units for rehabilitation and reconstruction	October 1989 ~~Earthquake~~ earthquake victims
Mortgage Credit Certificates	Admin: MBTCAC Int: Local governments	Tax credits for homeowners' mortgage interest payments	Low- and moderate-income first-time homebuyers
Weatherization Assistance for Low Income Persons	Admin: DEO Int: Private, non-profit organizations, local governments	Grants for home insulation and weatherization	Low income persons, especially elderly and handicapped
Low Income Home Energy Assistance	Admin: CSD Int: States, territories and indian tribes, local CSD agencies	Energy assistance grants including weatherization	Low income households
Single Family Mortage Revenue Bonds	Admin: Cities and counties Int: Private lenders and developers	Loans to acquire single-family residences	Low- and moderate-income first-time home buyers

Name of Program	Administering Agency and Intermediaries	Eligible Use of Funds	Target Population
	OWNERS OR RENTERS		
Section 312: Rehabilitation Loans	Admin: HUD Int: Local governments	Loans to rehabilitate units in community development block grant, urban homesteading, urban renewal, and code enforcement areas	Property owners in the indicated areas. Multi-family projects must also be in predominately low income areas with 51% low income occupants
Community Development Block Grants	Admin: HUD Int: Formula grants to Entitlement Cities and counties	Entitlement grants to cities and counties; local governments make grants, loans, loan guarantees, or interest supplements for rehabilitation or to facilitate the construction of new dwelling units	Very-low and low-income households
Section 203(k) - Rehabilitation Mortgage Insurance	Admin: HUD Int: Any person able to make a cash investment and the mortgage payment	Insures lenders against loss on loans to rehabilitate, refinance and purchase and rehabilitate a 1-4 unit dwelling	Low- and moderate-income households
Section 207 - Mortgage Insurance for Mobilehome Parks	Admin: HUD Int: Investors, builders, developers, and others who meet HUD requirements for mortgagors	Insures lenders against loss on loans to construct or rehabilitate mobilehome parks consisting of five or more spaces	Low- and moderate-income households

Name of Program	Administering Agency and Intermediaries	Eligible Use of Funds	Target Population
		OWNERS OR RENTERS - Cont.	
Solar Energy and Energy Conservation Bank	Admin: HUD Int: None	Grants or loans for purchase or installation of conservation and solar measures	Owners or tenants
Section 524 - Rural Housing Site Loans	Admin: FmHA Int: Self-help sponsors, public agencies, private non-profit organizations	Short term site acquisition loans	Rural FmHA assisted renters or cooperative owners
Section 525(a) - Technical and Supervisory Assistance Grants	Admin: FmHA Int: Public bodies, public or non-profit corporations	Grants for programs to assist residents to obtain or maintain adequate housing	Rural low income residents
Urban Pre-Development Loan Program	Admin: HCD Int: Local government organizations, cooperative housing corporations	Loans to pay for predevelopment costs such as land purchase, engineering fees, architectural costs, and legal fees	Very-low and low-income families and elderly or handicapped persons in urban areas
Deferred Payment Rehabilitation Loan Fund	Admin: HCD Int: Local government agencies, non-profit organizations	Loans to rehabilitate housing units	Low- and moderate-income households in local rehabilitation areas

Name of Program	Administering Agency and Intermediaries	Eligible Use of Funds	Target Population
	OWNERS OR RENTERS - Cont.		
Rural Land Purchase	Admin: HCD Int: Local government agencies, non-profit organizations	Loans to purchase land in rural areas	Very-low and low-income rural residents
Rural Pre-Development Loan Fund	Admin: HCD Int: Local government agencies, non-profit organizations, cooperative housing corporations	Loans to pay for pre-development costs such as land purchase, engineering fees, architectural costs, and legal fees	Very-low and low-income families and elderly or handicapped persons in rural areas
Farmworker Housing Grant Fund	Admin: HCD Int: Local government agencies, non-profit organizations, and cooperative housing corporations and homeowners	Non-recurring grants to construct and rehabilitate rental and owner-occupied units	Low-income farmworkers
California Housing Rehabilitation Program	Admin: HCD Int: Public or private entities, individuals, for-profit and non-profit corporations	Acquisition conversion and rehabilitation of owner-occupied and rental housing (including SRO's, group homes and cooperatives). Permanent housing only	Very low- and low-income households, seniors, disabled, rural residents
Senior Citizens Shared Housing Program	Admin: HCD Int: Local government and non-profit corporations	Grants to operate shared housing programs	Seniors

Name of Program	Administrative Agency and Intermediaries	Eligible Use of Funds	Target Population
		OWNERS OR RENTERS - Cont.	
SB 99: Redevelopment Construction Loan Act	Admin: Redevelopment agencies Int: Private lenders and developers	Loans for construction and limited rehabilitation of owner-occupied and rental units	Moderate- and high-income households (usually in rehabilitation areas)
Marks-Foran Residential Rehabilitation Act	Admin: Local government agencies Int: Non-profit corporations, direct loans to individuals	Loans to construct, rehabilitate, and acquire single-family and multi-unit dwellings	Low- and moderate-income households (usually in rehabilitation areas)
		HOMELESS PERSONS	
Emergency Shelter Grant Program (ESG)	Admin: HUD Int: Formula grants to certain local governments, states, CCC allocations made by Community Development Department.	Rehabilitation, conversion operating expenses (other than staff) and 20% social services for emergency shelter facilities, homeless prevention services. Aquisition or new construction ineligible	Homeless persons
Section 8 SRO Moderate Rehabilitation	Admin: HUD. Nationwide competition Int: Available to public housing agencies.	Rental assistance for rehabilitated single room occupancy hotels	Homeless persons
Supportive Housing Demonstration 1) Transitional Housing	Admin: HUD. Nationwide competition Int: Local governments, states, non-profit corporations, Housing Authorities	Acquisition, moderate rehabilitation and operating expenses and social services for transitional housing with services. Employment assistance programs. New construction ineligible	Homeless persons (targetted to deinstitutionalized persons, mentally disabled homeless, families with children and handicapped)

NOTE: For the purposes of this table, very low income is defined as 50% of County median income figure adjusted by household size, low income as 80% of median income, and moderate as 120% of median income.

HUD	=	U.S. Department of Housing and Urban Development
FmHA	=	U.S. Farmers Home Administration
DVA	=	California Department of Veterans Affairs
CHFA	=	California Housing Finance Agency
HCD	=	California Department of Housing and Community Development
FNMA	=	Federal National Mortgage Association
GNMA	=	Government National Mortgage Association
MBTCAC	=	California Mortgage Bond and Tax Credit Allocation Committee
DEO	=	California Department of Economic Opportunity
VA	=	U.S. Veterans Administration
DEO	=	California Office of Economic Opportunity
FEMA	=	Federal Emergency Management Agency
HHS	=	U.S. Department of Health and Human Services

Source: Housing Assistance in California: A Program Analysis, William S. Furry (A report prepared for the California State Assembly by The Rand Corporation) March, 1983; HCD, California Statewide Housing Plan; HCD, Directory of Housing Programs: Local, State Federal, March 1987; HUD, Homeless Assistance, July 1, 1989; and Contra Costa County Community Development Department

APPENDIX C

DESCRIPTION OF LAND USE, POPULATION AND EMPLOYMENT DATA

APPENDIX C
Description of Land Use, Population, and Employment Data Base

Land Use, Population and Employment Data Base Definition and Development

Data Sources

The following basic data sources were used in the development of the land use data base for the General Plan Review program:

- Summary of City and County General Plans, Contra Costa County Community Development Department, 1986.
- Composite General Plan Map compiled and prepared by the Contra Costa County Community Development Department, 1986.
- Contra Costa County Land Information System: 1985 Assessor Land Use Coded 600': 1" Base Map Sets Prepared by the Contra Costa County Community Development Department, 1985.
- 1980 Census of Population and Housing, Summary Tape File 3, Block Group Listings, U.S. Department of Commerce, Bureau of the Census
- Projections '85: Census Tract Projections, Association of Bay Area Governments, 1985.
- Projections '87: Census Tract Projections, Association of Bay Area Governments, 1987.
- Map of City and County Development Projects: 2000': 1" Map depicting the locations of all projects under construction, approved or applied for to a City or County Planning Agency. Compiled and prepared by the Contra Costa County Community Development Department, 1987.
- Map overlay at 2000': 1" scale identifying areas which were vacant, uncommitted by project approval, and designated for urban Development in the City or County General Plan. Prepared by the Contra Costa County Community Development Department, 1987.

Description of Data Sources

Each of these sources is briefly described below:

The publication Summary of City and County General Plans depicts the adopted land Use element maps of each of the eighteen cities and the unincorporated area of Contra Costa County. The report also points out the differences between City and County policies in the unincorporated "Sphere of Influence" areas.

The Composite Land Use Map is a map which was prepared based upon the designations and densities found in Summary of City and County General Plans, translated from the many different density designation schemes of the various jurisdictions into one common set of land use designations.

The Land Information System Land Use Coded 600': 1" scale maps consist of color coded maps identifying the current use of all parcels in the county as determined for assessment purposes. These maps were created from a complete parcel listing from the Land Information System as of 1985.

The Bureau of the Census STF3 listings contain Census Tract and Block Group information on Population and Housing units from the 1980 Census. Although they represent sample data reflecting approximately 1 out of 6 households, the were deemed adequte for the purpose of allocating total Census Tract population and housing unit data to the Traffic Zone (sub Census Tract) Level.

Projections '85 and Projections '87 are the regional projections series produced by the Association of Bay Area Governments (ABAG). These documents contain data and projections for the region, each county in the Bay Area and each city Sphere of Influence area. Data from the series for the Census Tract Level available on floppy computer disks formed the basis for the default estimation values used in the General Plan Review data base in terms of vacancy rates, persons per household, household income and jobs per household. In addition, this source includes employment estimates for each census tract by major employment type: agriculture, forestry and mining, manufacturing, wholesale trade, retail trade, services, and other employment. Errors in coding employment to census tracts by ABAG were followed up with that agency, so that corrections to both data bases could be made.

The 2000': 1" Projects Map was prepared by manually plotting the results of a survey of the City and County Planning Agencies regarding changes which had occurred since the 1985 base year. These changes included specific development projects which had been built since 1985, projects approved since 1985 and proposed projects which were active at the time of the survey. Each of the projects was coded by type, and entered into a log corresponding to the mapped project numbers. This map is on file at the offices of the Contra Costa County Community Development Department.

The 2000': 1" overlay map was assembled by comparing the area designated for urban development in the Composite General Plan with the 1985 Land Use Maps and the Projects Map to delineate the area which had not yet been committed to development, but was considered developable by adopted local land use policy. These areas were then measured by land use type within each Traffic Zone and entered into the computer data base as transactions. A full discussion of the land use transactions as they are applied to the development of the database is included as the last section of this appendix.

Definition of Traffic Zone Boundaries

The first step in defining the database structure involved recognition that the form of the database is governed by its most highly defined use. The EMME2 transportation modelling system was the most highly defined user of the database, as inputs into the traffic model. Thus, traffic zones were early identified as the appropriate unit of geography for allocating the numbers of people, acres, jobs by type, households and incomes within Contra Costa County from the higher level Census Tract data and estimates available.

To the extent possible, the boundaries of the traffic zones were drawn with the following factors in mind:

1. Traffic zones were to be compatible with Bureau of the Census geography, i.e., zones must aggregate to census tracts.

2. Traffic zones were to contain an area which can be attributed to links in the transportation system for the purpose of trip generation and distribution.

3. Traffic zones were to reflect logical groupings of land use, which contribute to well defined traffic flows on transportation system links.

4. Traffic zones were to reflect large area specialized uses, such as regional shopping centers, and other areas of large volume traffic generators.

5. Traffic zones boundaries were to respect topography in addition to existing and expected circulation system features.

A total of 517 traffic zones were defined for the area within Contra Costa County, with another 40 zones defined in the region outside the County. Since there are approximately 160 census tracts in the County, there are an average of 3 to 4 traffic zones within each tract. The zones outside the County corresponded to the Metropolitan Transportation Commission (MTC) Super Zones, which in general aggregate several census tracts.

Establishing Base Year Benchmark Data

In order to establish base year data compatible with the requirements of the transportation model, data for 1980 by census tract and block group were compared to estimates of the Association of Bay Area Governments' Projections '85, with annual Certified Population Program building permit additions data for April 2, 1980 through 1985 added in to approximate the end of 1985 benchmark.

The late 1985 benchmark data were then visually compared to a set of color coded land use maps based upon a complete parcel listing of the Contra Costa County Assessor's Use codes, in order to allocate (disaggregate) the 1985 Census Tract level projections to the smaller traffic zone level. The data allocated for each traffic zone included the following:

1. Number of single family housing units in each traffic zone, as well as an estimate of the vacancy rate, average persons per unit, and number of households (occupied housing units) in the zone;

2. Number of multiple family housing units in each traffic zone, as well as an estimate of the vacancy rate, average persons per unit, and number of households (occupied housing units) in the zone;

3. Total household population in each traffic zone, as well as non-household population (persons living in group quarters such as dormitories, jails, etc.);

4. Average household income;

5. Average number of employed residents per household;

6. Estimate of the number of jobs in the traffic zone, divided into the following employment categories:

   a. Agriculture, Forestry & Mining

   b. Manufacturing

   c. Wholesale Trade

   d. Retail Trade

   e. Services (includes health and education workers)

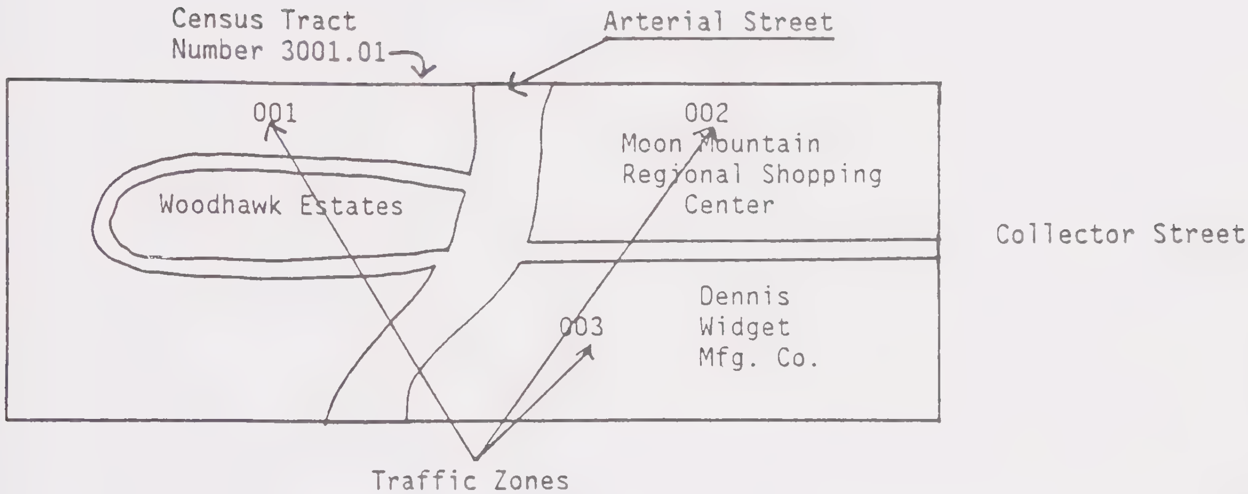
   f. Other (includes most private office workers and some public employees);

5. Estimate of the number of employed residents in the traffic zone.

The process by which estimates of the statistics above were developed for each traffic zone began by first distributing 1980 Census tract values to traffic zones based upon visual inspection of the land use maps, i.e. esimating how much of the census tract total should be allocated to each smaller traffic zone. Secondly, the 1985 ABAG census tract estimates were compared with the 1980 data and the land use maps. An estimate of self employment within predominantly residential areas was proportioned among the traffic zones on the basis of housing units in the zone.

Thus, the 1980 data based upon the Census, along with the housing completions data provided to the Department Of Finance Population Research unit, along with critically reviewed employment estimates provided the basis for the 1985 data set. A hypothetical assignment of data within a census tract is portrayed in Figure 1, which demonstrates in a highly simplified way the rationale behind the distributions which were performed from the census tract to the traffic zone level.

Figure 1
Allocation of a Fictional Census Tract
Into Three Trafic Zones



1. Basic Data for C.T. 3001.01

	Single	Multiple
Vacancy Rates:	3%	4%
Persons per household:	2.8	1.5
Census STF 3, workers with no journey to work:	40 residents	

ABAG allocation of Jobs to Tract:

Ag., Forestry, Mining	--
Manufacturing	4,000
Wholesale Trade	20
Retail Trade	1,500
Sevices	100
Other	6

Residential Distribution:

S.F. Units	700
M.F. Units	300

3. Allocation Procedure Applied

	TZ 001	TZ 002	TZ 003
Demographics			
Households	967	---	---
Population	2333	---	---
Jobs			
Ag/Fr/Mine	----	---	---
Manufactng	----	---	4,000
Wholesale	----	---	20
Retail	----	1.500	-----
Services	40	60	-----
Other	----	-----	6
Totals	40	1,560	4,026

2. Population Estimate:

700 units x .97 occupancy = 679 households x 2.8 persons/hshld = 1901 persons
300 units x .96 occupancy = 288 households x 1.5 persons/hshld = 432 persons
totals = 967 households, 2333 persons

Estimation of Further Development Potential

A "transaction" system was developed and incorporated into the database in order to estimate the future development potential of lands which were vacant in 1985, but have since been developed, approved or proposed for development, or designated for future urban development under the existing County or city General Plans. Each transaction type represents a change in the status of land, primarily a change from undeveloped or agricultural land to urban uses, which is then added to the 1985 land use base, by traffic zone.

Each transaction type has been coded according to the following categories:

1. "1987" denotes a project which had been built since 1985, or was under construction at the time of the survey in 1987. It is assumed that all of the projects within this category will be built at the densities indicated, since development rights are generally vested.

2. "AP" denotes an approved development project, which has been considered a city or County decision making body. It is assumed that the density indicated in the approval is what will be built. This is less certain than the assumption in (1) above, since some projects will not proceed, others may be modified at the request of the project proponent or the agency . The estimates included in the Countywide General Plan Review scenarios presume that these projects will all be built as approved.

3. "PP" denotes projects which were proposed and pending before the Planning Agencies for approval at the time of the survey. It is assumed that the densities of the proposed projects are generally consistent with the General Plan designations of the cities or the County, although there is less certainty associated with the unit or square footage yields of these projects than with the "1987" or "AP" projects.

4. "FP1" denotes a vacant area which is not associated with any recently constructed, approved or proposed project, but which is designated for development according to the current General Plans of the County or the cities. There is less certainty associated with the FP1 transactions than with the first three categories.

5. "FP2" denotes those land areas or projects which represent an addition to the amount of land now designated for future urban development under the existing County and city General Plans (the "Spread" alternative). Some of these additional "Spread" projects are General Plan Amendments which were pending before a hearing body at the time of the survey; some of the projects are General Plan studies now underway by the County or a city; and some of the projects are significant amendment requests that have not been formally submitted to the County or a city, but which have been studied during this General Plan Review program. Most of these "FP2" transactions are denoted by both a "CO" in Open Space and an "EX" in the area newly designated for development.

6. "EX" denotes expansion areas under the "Spread" land use alternative, i.e. lands which are not now designated for development, but have been tested as to the impacts of development. The "EX" category is always accompanied by a "CO" category, which is generally a contraction of previously identified open space lands. However, in some alternatives "CO" denotes a contraction of a certain urban land use with an accomponaying expansion of another urban land use, such as could occur under a redevelopment plan.

7. "FP3" transactions include all of the "FP1" transactions (buildout of vacant land under the current General Plans), accompanied by some additional transactions, which represents the difference in future development potential under the existing and proposed plan. The full buildout of the proposed General Plan land use map is equal to the sum of the existing 1985 database; development under the "1987" (under construction), "AP" (approved projects), and "PP" (proposed projects) transactions; and the "FP3" transactions.

Each planning department in the County was surveyed to determine what specific development projects had been built, was under construction, had been approved or proposed since 1985. This task lead to the creation of two binders containing listings of all of the projects in the cities and the County, which were then assigned the following codes:

1. traffic zone number;

2. location (city or area);

3. description of project (number of single or multiple family units, square footage of commercial or industrial building, project sponsor, acreage, status/comments) and assigned project reference number;

In order to avoid gross exaggeration of the holding capacity of the remaining undeveloped lands, the first task in the estimating process segregated those projects which were committed to development at certain densities from the lands upon which development could be allowed, but for which it was not yet proposed. Projects were further classified in terms of the degree of certainty related to density, i.e., an approved project is much more likely to be built at the stated density than at a hypothetical density based upon the standard default values in the data base.

Areas designated for future urban development in city and County General Plans, but which were vacant and not associated with any pending or approved project proposals, were then planimetered (measured for their acreage) and estimates of their development potential was derived. In general, default values were assigned to acreages to convert gross acreage to net acreage, then the highest value in the density range allowed by the respective land use plan was applied to yield a buildout estimate.

The estimating values which were used as default densities in order to calculate these buildout figures are presented in Table 1.

Table 1

Land Use
Default Estimating Values

Land Use	Net to Gross Acres	Density (units or FAR*)	Estimating Value (units or FAR*)
Commercial (Retail)	75%	0.5	0.375
Office	75%	0.8	0.6
Light Industry	75%	0.4	0.3
(Heavy) Industry	75%	0.3	0.225
Single Family-Very Low Density	75%	1.0	0.75
Single Family-Low Density	75%	3.0	2.25
Single Family-Medium Density	75%	5.0	3.75
Single Family-High Density	75%	7.0	5.25
Multiple Family-Low Density	80%	11.0	8.8
Multiple Family-Medium Density	80%	19.0	15.2
Multiple Family-High Density	80%	27.0	21.6
Multiple Family-Very High Density	80%	45.0	36.0

Note: * (FAR) Floor area ratio is calculated by dividing average building square footage by lot size.

Source: Contra Costa County
Community Development Department
General Plan Review Program

The amount of development potential estimated in this manner is characterized for each traffic zone as an individual "FP1" transaction. Each increment of development potential was then applied to the various estimating parameters of the census tract in which it was located (average vacancy rate, average people per household, etc.) to come up with an estimated buildout population and density, as described in the next section.

Application of the Database to the EMME2 Traffic Demand Model and Creation of Data Sets

Once the transactions were coded into the database, a process termed "EMME2 Driver Production" was undertaken. EMME2 is the name of the specific licensed software program that was used to run the transportation computer model. This process consisted of calculating the total population, number of households, median household income, persons per household, employed residents per household, and employment (by retail, services and other categories) for each of the 517 traffic zones.

The estimating parameters which were used for these calculations in each census tract were derived from the most recent Association of Bay Area Governments (ABAG) projection series (Projections '87). For example, ABAG's estimate of the average future household size in the Crockett area for the year 2005 was used to calculate the population expected from the buildout of housing units under the various General Plan alternatives.

A series of separate data sets were constructed, which consisted of a combination of different transaction types added to base data sets for 1980 and 1985. The "composite," "constrained," "spread," and "proposed" data sets described below are the major land use alternatives or scenarios that were tested under this General Plan Review program:

1. EMME80 - This is a base data set consisting of the 1980 U.S. Census data allocated down to the traffic zone level. A high degree of confidence can be placed in this data set.

2. EMME85 - This set builds upon the 1980 data by including all housing units and employment added between 1980 and the end of 1985. It is thus an estimate of the total population, number of jobs and housing units, etc. in the County at the end of 1985. A similarly high degree of accuracy is expressed in these allocations.

3. BASECASE - The "basecase" data set is equivalent to the current situation in the County plus buildout of all development projects that have already been approved. Thus, this set includes the data in EMME85 plus all transactions designated "1987" and ""AP". Confidence in the overall accuracy of this data set is not quite as high as EMME80 and EMME85 above, since some of the approved projects may never be built, as financing or other variables fail to materialize. Nevertheless, there is a relatively high degree of probability that the vast majority of the approved projects under this scenario would eventually be built, with construction of all but the largest projects expected to be completed by 1992-1993.

4. COMPOSITE - This data set contains the data in BASECASE, as well as the "PP" (proposed project) category and the "FP1" transactions (buildout of all vacant land now planned for development under the city and County General Plans as of 1988).

5. CONSTRAINED - This data set consists of the "composite" data set, minus some job growth that is not expected to occur under existing city and County plans until after the twenty year planning period. While all of the housing growth planned in the city and County General plan is expected to take place within the next twenty years, some of the employment growth will not occur during that time period due to market and other constraints. Thus, this data set constrains employment growth in the County by some 38,000 jobs over the twenty year period, and also constrains job growth outside the County in the rest of the San Francisco Bay region. The constraint analysis was prepared in consultation with various City Planning Departments and the Association of Bay Area Governments.

   (In brief, consisted first of identification of the maximum capacity for commutation from counties outside the region to Bay Area jobs, based upon assumptions regarding vehicle occupancy, number and volume of lanes, and estimated transit ridership. The resultant estimated commuters were used as a proxy measure for jobs held in the region by extra-regional employed residents. These jobs were then reserved for these commuters in the model and assigned to specific employment centers such as the Hacienda Business Park in Pleasanton and Bishop Ranch in San Ramon. Next, total trip productions (Home-based work trips summed over all traffic zones, both in Contra Costa and in the external zones in the Bay Area) were compared with total attractions (jobs summed over the same geography). Overall, there was a substantial imbalance of attractions over productions (some 156,000 trips). These excess attractions were constrained in the form of jobs assumed to be created after the year 2005.

   These findings are consistent with published anayses by ABAG urging the creation of more housing throughout the region in order to avoid the implicit constraint of jobs (and thus, economic expansion) by the end of the projection period.

6. SPREAD - This data set consists of buildout of existing General Plans plus additional development that is not now permitted under the plans. It represents a land use alternative that was tested during the Geenral Plan Review prorgam in order to determine the possible impacts of allowing a significant amount of development in new areas of the County, according to some informal landowner and other requests.

   In order to balance trip productions and attractions in this alternative, a CALTRANS methodology for extrapolation of traffic modelling data was used to extend the ABAG 2005 projections of all model variables for the area outside Contra Costa County to the year 2015. The CALTRANS equations for such exptrapolation are as follows:

The extrapolated figures were then combined with the "Spread" alternative land use data for Contra Costa County and a new trip generation routine was run. In this alternative, a greater imbalance (constraint) resulted from the comparison of trip productions and attractions than was present in the "Composite" alternative. This necessitated another application of the constraint method described above. Based upon these findings, further evaluation of the "Project" alternative was conducted, result in constraints being applied in that alternative as well.

7. PROPOSED - This data set represents the anticipated buildout of the proposed County General Plan over the twenty year period (assuming some of the job growth is constrained according to market demands). Thus, this "preferred" data set or land use alternative was constructed by combining the "basecase" data set with the "FP3" transactions.

APPENDIX D

PLANNED TRANSPORTATION PROJECTS INCLUDED AND NOT INCLUDED IN THE FINANCIALLY CONSTRAINED PLAN

App. D

ID	Project Description
* 2	SR 4: SR 160 to Cypress, 2 to 4 lanes w/ couplet.
* 4	SR 24: East portal of Caldecott to Orinda, add WB HOV access to tunnel.
* 5	SR 242: Solano Wy SB offramp, 1 lane to 2.
* 6	SR 242: Clayton Rd., from Diamond to NB 242, add SB onramp
* 7	SR 242: Concord Ave, add NB loop onramp w/ aux. lane to Grant, (Phase 1&1a)
* 8	I-580: Richmond San Rafael Bridge to I-80. Construct 6 lane freeway, add HOV lane from Central to I-80.
* 9	I-680: Alameda County to Rudgear, add 2 HOV lanes.
* 10	I-680: Rudgear to SR 24, reconstruct I-680/SR 24 freeway connectors at 3 lanes, remove Newell SB ramps, and add full interchange at Olympic. SR 24 to SR 242, 6/8 lanes to 10, add SB onramp from Gregory to Monument, add auxiliary lanes between Olympic and Ygnacio Valley, add SB auxiliary lane from Olympic to So. Main.
* 11	I-680: Willow Pass to Marina Vista, 4 lanes to 6.
* 12	I-680: Concord Ave. Realign NB ramps to Burnett, add auxiliary lane from Willow Pass to Concord Ave.
* 13	I-680: Benicia-Martinez Br, 4 lanes to 6, add 2 toll booths.
* 14	I-680: Sycamore Valley Rd, construct 260 space park&ride lot.
	Total State Projects (Near Term)
* 15	BART: Systemwide. Increase train frequencies from 9 to 4.5 minutes. $475 million total project cost, $158 million allocated to CC County.
* 16	BART: El Cerrito Del Norte, 1593 spaces to 1893.
* 17	BART: Lafayette Station, 1096 spaces to 1516.
* 18	BART: Pleasant Hill Station, 1652 spaces to 2852.
* 19	BART: Richmond Station, 754 spaces to 954.
* 20	CCCTA: Systemwide. Increase peak bus service from 77 to 97 buses. Includes downtown shuttles in Concord and Walnut Creek and subscription express bus.

ID	Project Description

Total Transit System Proejcts (Near Term)

* 21 Arnold Way: 1000' east of Morello to 500' west Morello, 2 lanes to 4.

* 23 Bailey Rd: SR4 to Willow Pass, 2 to 4 lanes.

* 24 Bancroft Rd: Hookston to Monument, 0 lanes to 4.

* 25 Bancroft Rd: Minert to Ygnacio Valley, 2 lanes to 4.

Camino Pablo: Realign, add turn lanes.

* 27 Camino Tassajara: Crow Cyn to Blackhawk, 2 lanes to 4.

* 28 Central: Dainty (at Minnesota) to Sycamore, 0 lanes to 4.

* 29 Coggins Dr: (north-south segment) 2 lanes to 4.

* 31 Dainty Ave: Fairview to Minnesota, 2 lanes to 4.

* 32 Deer Valley Rd: Davison to Lone Tree, 0 lanes to 4.

* 33 Diablo Rd: El Cerro to Green Valley, 2 lanes to 4.

* 34 East 18th St: Cavallo to SR 4/160, 2 lanes to 4.

* 35 El Cerro Blvd: I-680 to Danville, 0/2 lanes to 2.

* 39 James Donlan Blvd: Lone Tree to Sommersville, 2 lanes to 4.

* 40 James Donlan Blvd: Somersville Rd to Buchanan 0 lanes to 4.

* 41 Jones Road: Coggins Ln to BART parking lot. Construct exclusive bus lanes.

* 42 Laurel Rd: SR 4 to Neroly, 2 lanes to 4/6.

* 43 Lone Tree Way: Sand Creek Rd to east city limit, 2 lanes to 4.

*174 Morello Ave: North of SR 4 to Pacheco, realign and replace ATSF grade separation.

* 45 Richmond Parkway: Unit I (Castro St., Garrard Blvd, Hensley overcrossing)

* 48 Richmond Parkway (Sec. 2 and 3): Hensley to Parr, 0 lanes to 4.

* 49 Richmond Parkway (Sec. 5): Giant to San Pablo Ave:

ID	Project Description
	0 lanes to 6.
*185	Richmond Parkway: Blume to I-80, add interchange
*185a	Richmond Parkway: San Pablo to Atlas I/C: 5 lanes to 6.
* 50	Oak Rd: Walden to Jones, 2 lanes to 4.
* 52	Olympic Blvd: Newell to Center, 2 lanes to 4.
* 54	Port Chicago Hwy: Bonifacio to Clayton, 2 lanes to 4 with 2-lane extension to Clayton via Sunset.
*216	San Ramon Valley Blvd: Hartz to Greenbrook, 2/4 lanes to 4.
*217	San Ramon Valley Blvd: Greenbrook to Alcosta, 2/4 lanes to 4.
* 56	Sand Creek Rd: Laurel Rd extension to Lone Tree, 0 lanes to 2.
* 57	Sommersville Rd: James Donlan to Buchanan, 2 to 4 lanes.
* 58	Sommersville Rd: SR4 to Pittsburg-Antioch Hwy, 2/4 to 6 lanes with SPRR grade separation.
* 59	Sommersville Rd/4th St: Pittsburg-Antioch Hwy to L St, 2 lanes to 4.
*59a	S. Broadway: Newell to Rudgear, 0 lanes to 2.
* 60	Southern Pacific ROW: Bancroft to Coggins Dr. Construct 4 lane road.
*243a	Willow Ave/SP Ave/Parker Ave: realign intersection.
*231	Treat Blvd: WC Channel to Cherry, 6 lanes to 8.
*63A	SR 4: (Unit 1) I-80 to Cummings Skyway, construct 4-lane freeway with interchanges at Willow/Sycamore and Franklin Cyn.
*65A	SR 4: Willow Pass Rd (Concord) to Bailey, 4 lane to 6 with climbing lanes, and lower grade.
*65B	SR 4: Bailey Rd. Interchange Reconstruction
*65C	SR 4: Bailey to Railroad, 4 to 6 lanes
* 67	SR 4: SR 160 to Empire, 4 lanes to 6

ID	Project Description
* 68	SR 4: Cypress to Sunset, 2 to 4 lanes.
* 69	SR 4: Sunset to Sellers, 2 lanes to 4.
* 73	I-80: Carquinez Bridge to Willow, 6 lanes to 8 lanes, includes the bridge.
* 74	I-80: Willow Avenue to Bay Bridge. Add HOV lanes from Willow to Bay Bridge, add aux. lanes, revise interchanges. $271 million total project cost, $111 million in CCC
* 77	SR 242: SR 4 to I-680, Add HOV lanes, part of Contra Costa Commuterway.
* 79	SR 242: Concord Ave vicinity, add SB ramps w/ aux. lane from Solano to Concord.
* 80	I-680: Willow Pass Rd. Add NB onramp loop.
*80A	I-680: Treat Blvd, reconstruct I/C.
* 82	I-680: SR 4, reconstruct interchange w/ 2-lane freeway connectors.
* 83	I-680: Benicia-Martinez Bridge. Construct parallel bridge.
* 84	I-680: Bollinger Cyn Rd, construct 300 space park&ride lot.
*84a	I-680: Stone Valley Rd, revise ramps
*84b	I-680: Diablo Rd to Bollinger Cyn, construct aux. lanes
* 85	AC Transit: Construct transfer centers at El Cerrito Del Norte BART station and Contra Costa College Improve bus loading zones at El Cerrito Plaza BART, Richmond BART, and Hilltop Mall.
*85a	BART: Concord line, extend rail line to W.Pittsburg
*85b	BART: Richmond line, extend rail line to CC College and Hilltop
* 87	BART: El Cerrito Del Norte, 1893 spaces to 2393.
* 88	BART: Lafayette Station, 1516 spaces to 2216.
* 89	BART: Orinda station, 1146 spaces to 1646.

ID	Project Description
*89a	Contra Costa Commuterway: SR 242 to I-680, busway on SPRR ROW from SR 242 @ Clayton to I-680 @ Rudgear.
* 91	Alhambra Avenue: SR 4 to Benham Dr. Widen from 2 to 4 lanes.
* 92	Appian Way: Michael to San Pablo Dam Rd, 2 lanes to 4.
* 93	Balfour Road: Realigned SR 4 to old SR 4, 2 lanes to 4.
* 94	Barrett Ave: Garrard to 6th, 2 lanes to 4.
* 95	Bates Ave: Port Chicago Hwy to Arnold Ind. Way (at Lowe), 0/2 lanes to 4.
* 96	Bethel Island Rd: Taylor to Cypress, 2 lanes to 4.
* 97	Byron Highway: Delta to Cypress, 0 lanes to 2.
*97a	Byron Highway: SR 4 to Delta, upgrade to 2 lane arterial
* 98	Bollinger Canyon Rd: San Ramon Valley Blvd to Camino Ramon, 6 lanes to 8.
*101	Buskirk Ave: Monument to Coggins, 2 lanes to 4.
*109	Church Ln: San Pablo Ave to El Portal, 2 lanes to 4.
*110	Clayton Rd: Main St Bypass to El Camino, 2 lanes to 4.
*111	Clayton Rd: Chestnut to Grant, 4/6 lanes to 6.
*112	Concord Blvd: Sixth to Kirker Pass, 2 lanes to 4.
*113	Concord Blvd: City limit to Main St Bypass, 0 lanes to 4.
*114	Concord Blvd: Main St Bypass to Marsh Crk Rd, 0/2 lanes to 2.
*117	Crow Cyn Rd: Alameda Co line to Bollinger Cyn, 2 lanes to 4.
*119	Crow Canyon Rd: Alcosta to Camino Tassajara, 4 lanes to 6.
*121	Cutting Blvd: Garrard to Carlson, reconstruct at 4 lanes, with SPRR grade separation.
*122	Cypress Rd: Machado Ln B. Island Rd, 2 lanes to 4. 2 lanes to 4.

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ID Project Description

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*123 Cypress Rd: Bethel Isl Rd to Sandmound, 0 lanes to 2.

*125 Delta Rd: O'Hara to Old SR 4, 0 lanes to 2.

*127 Diablo Rd: I-680 to Camino Tassajara, 2 lanes to 4.

*128 Diamond Blvd/Marsh Dr: Construct 4-lane road to Sally Ride. Center Ave: Pacheco to Diamond, 2 lanes to 4.

*129 Dougherty Rd: Crow Cyn to County Line, construct 2 lane to expressway standards

*133 El Portal Dr: Church to I-80, 2/4 lanes to 4.

*134 El Portal Dr: I-80 to San Pablo Dam Rd, 2 lanes to 4.

*135 Empire Ave: Oakley Rd to Lone Tree, 2 lanes to 4.

*136 Evora Rd: Willow Pass (W Pittsburg) to Willow Pass (Concord), 2 lanes to 4.

*136AEvora Rd: Willow Pass (Concord) to Port Chicago Hwy, 0 lanes to 2

*138 Fairview Ave: Balfour to old SR 4, 0 lanes to 4.

*138aFairview Ave: Lone Tree to Balfour, widen and realign, 2 lanes to 4.

*139 Farm Bureau Rd: Clayton Rd to Willow Pass, 2 lanes to 4.

*140 Fitzgerald Dr: Pinole Shopping Ctr to Park Central, 0 lanes to 2/4.

*141 Fostoria Way: Hilsher Way to San Ramon Valley Blvd, 0/2 lanes to 4 with I-680 overcrossing.

*144 Galindo St: Willow Pass to Laguna, 4 lanes to 6.

*146 Gateway Blvd: SR 24 to Ivy Dr, 0 to 2 lanes.

*147 Geary Rd: N Main to Pleasant Hill Rd, 2 lanes to 4.

*150 Harbour Way: Barrett to Pennsylvania, 2 lanes to 4.

*152 Hilltop Dr: San Pablo to No Richmond Bypass, 0 lanes to 4.

*153 Hookston Rd: Buskirk to Bancroft, 2 lanes to 4.

*154 Howe Road: Arnold Dr to Pacheco, 2 lanes to 4.

*157 Kirker Pass Rd: Buchanan to Concord Blvd, 4 lanes

ID	Project Description
	to 6.
*158	Laurel Rd: Neroly to Delta Expway, 0 to 4 lanes with SPRR grade separation.
*159	Laurel Rd: Delta Expway to Hillcrest, 0 to 4 lanes.
*159a	Laurel-Cypress Connection: SR4 to Cypress Rd w/o Sellars 0/2 lanes to 4 w/ grade separation @ ATSFRR.
*159c	Live Oak Ave: SR4 to Oakley, 2 lanes to 4.
*160	Lone Tree Way: SR 4 to Antioch city limit, 2 to 4 lanes w/ SPRR grade separation.
*161	Lone Tree Way: SR 4 to Delta, 0 to 2 lanes.
*162	Neroly Rd: SR 4 to Laurel, 2 to 2/4 lanes.
*163	Lone Tree Way: James Donlan to Sand Creek Rd, 2 lanes to 4.
*164	Main Street: Port Chicago Hwy to Waterfront Rd. Close 2 lane road.
*165	Main St. Bypass: Clayton Rd to Concord Blvd, 0 lanes to 4.
*166	Marina Way: Ohio to Bissel, 2 lanes to 4.
*167	Marsh Dr: Center Ave to Arnold Ind Pl, 2 lanes to 4.
*172	Monument Boulevard: Contra Costa Blvd to Buskirk Ave. Widen from 4/6 to 6 lanes.
*175	Mt. Diablo Blvd: SR 24 to California, 4 lanes to 6.
*177	N. California Blvd: N. Main to Mt. Diablo, 4 lanes to 6.
*178	N. Main St: San Luis to California, widen SB 2 lanes to 3.
*179	N. Main St/Parkside Dr Bypass: California to Ygnacio Valley, widen SB 2 lanes to 3. California to I-680, widen NB 3 lanes to 4. Ygnacio to Pringle, widen widen NB 2 lanes to 3. Pine St to I-680, construct NB road west of BART tracks along Kazebeer, 0 lanes to 3.
*186a	Oakley Rd: Neroly to Empire, 2 lanes to 4.
*184	Richmond Parkway (Sec. 4): Parr to Giant, 0 lanes to 6, with ATSFRR and SPRR grade separations.

ID	Project Description
*186	Oak Grove Road: Peach to Monument, 4 lanes to 6.
*187	O'Hara Ave: SR 4 to EBMUD, 2 lanes to 4, w/ couplet.
*189	O'Hara Ave: Lone Tree to Central, 0 lanes to 4.
*190	Old Ranch Rd: Alcosta to Dougherty, 2 lanes to 4.
*191	Olympic Blvd: California to I-680, 4 lanes to 6.
*199	Pinole Valley Rd/Tenant Ave/Fernandez: I-80 to San Pablo Ave, 2 lanes to 4 with Fernandez 2 lanes WB and Tenant 2 lanes EB.
*202	Port Chicago Highway: Main St to Wharf Dr. Close 2 lane road.
*208	Rheem Blvd: Rumrill to San Pablo Ave, 2 lanes to 4.
*210	Rudgear Rd: S. Broadway to Danville Bl, 2 lanes to 4.
*211	Rumrill Blvd: Brookside to south city limit, reconstruct at 4 lanes.
*212	San Pablo Ave: I-80 to north city limit, reconstruct at 6 lanes.
*214	San Pablo/Parker Ave: Willow to I-80, 2/4 lanes to 4.
*215	San Pablo Dam Road: I-80 to Barranca, 4 lanes to 6.
*215a	SP Dam Rd: Barranca to Appian, 3 lane couplet each way.
*215b	SP Dam Rd: Appian to Castro Rch, 5th lane w/ intersection widening.
*218	Sand Creek Rd: Realigned SR 4 to old SR 4 with SPRR grade separation, and Marsh Cr. bridge.
*223	Sycamore Ave: Refugio Valley to SR 4 at Willow, 2 lanes to 4.
*228	Third St/Fourth St: L St to A St, convert to one-way couplet, 3rd St WB and 4th St EB.
*232	23 St: San Pablo Ave to south city limit, reconstruct at 4 lanes.
*233	23 St: I-580 to Broadway, 4 lanes to 6 with SPRR grade separation.
*234	Unnamed road (Brentwood eastside bypass): Lone Tree Way to S. Fairview extension (at old SR 4), 0 lanes to 2.

ID	Project Description
*235	Valley View Rd: Appian to S.P. Dam Rd, 2/4 lanes to 4, w/ triangle improvements.
*276a	Delta Expressway: SR 160 to SR 4 south of Brentwood, construct 4-lane freeway north of Balfour and 2-lane expressway s/o Balfour.
*237	Walnut Blvd: Oak to S. Fairview extension, 2 lanes to 4.
*239	Waterfront Road: Main St to Solano Way. Close 2 lane road.
*240a	West Leland Rd: Bailey to Willow Pass East. 0 to 4 lane
*243	Willow Ave: I-80 to San Pablo Ave, 2 lanes to 4.
*245	Willow Pass Rd: SR 4 to Bailey Rd, 2 to 4 lanes.

ID	Project Description
64	SR 4: I-80 to Alhambra Ave, 4/6 lanes to 6.
274	SR 4: Railroad to SR 160, 4 lanes to 6 plus HOV's and WB offramp at L St, and remove G St ramps.
70	SR 4: Sellers to county line, 2 lanes to 4.
72	SR 24: Caldecott Tunnel, 6 lanes to 10.
296	SR 84 (Vasco Rd): I-580 to SR 4, construct 4-lane freeway. $180 million total project cost, $90 million in CC County.
76	SR 239 (Byron Hwy): I-580 to SR 4, construct 4-lane freeway. $80 million total project cost.
278	I-680: SR 242 to SR 4, 6 lanes to 8.
279	BART: Concord line, extend rail from W. Pittsburg to Hillcrest
90	Alcosta Blvd: San Ramon Valley Blvd to Crow Cyn, 2/4 lanes to 4, with partial coverleaf interchange.
	Arnold Industrial Way: Solano to Port Chicago Hwy, 2 lanes to 4.
	Bancroft Rd. Hookston to Monument, 4 lanes to 6.
99	Boulevard Way/Tice Valley Road: Del Hambre Cir to Danville Bl, 2 lanes to 4 and extend to Danville Bl.
100	Buchanan Rd Bypass: Kirker Pass to Sommersville, 0 lanes to 4.
102	California Ave: Railroad to Loveridge, 2 lanes to 4 and realign west end to Center Dr.
103	California Blvd: Olympic to Newell, 4 lanes to 6.
104	California Blvd: Newell to S Main, 0 lanes to 4.
105	California St: Tillibee to 5th, 0 lanes to 2.
106	Camino Tassajara: Crow Cyn to Blackhawk, 4 to 6 lanes.
107	Camino Tassajara: Blackhawk to county line, 2 lanes to 4.
254	Canal Rd: Taylor to Bethel Isl Rd, 2 lanes.
108	Center Ave: Blackwood to Pacheco, 2 lanes to 4.
115	Contra Costa Blvd: Gregory to Monument, 6 lanes to 8.

ID	Project Description
116	Cowell Rd: Treat to Galindo, 2 lanes to 4.
120	Cummings Skyway: San Pablo Ave to I-80, 0 lanes to 2.
124	Deerwood Dr/Fostoria Way: Old Mill to San Ramon Valley Blvd via realigned Omega Rd, 0/2 lanes to 2 lanes, extend Ryan Industrial Ct to Crow Cyn opposite Twin Creeks, and close Old Crow Cyn east of Ryan Industrial and north of Purdue.
126	Detroit Ave: Laguna to Clayton Rd, 2 lanes to 4.
131	E. 14 St/Pittsburg-Antioch Hwy: Railroad to Loveridge, 2 lanes to 4.
132	Eden Plains Rd: Brentwood Ave to SR 4, 0 lanes to 2/4.
137	Fairmont Ave: Colusa to Arlington, 0 lanes to 2.
142	Fostoria Way: San Ramon Valley Blvd to Deerwood Pl, 0 lanes to 4.
	Galaxy Way: Commerce to Market, raise SR 242 and extend road at 6 lanes.
145	Galindo St: Laguna to Cowell, 4 lanes to 6.
148	Goodrick Ave: Parr to N. Richmond Bypass, 2 lanes to 4.
149	Harbour Way: Cutting to Bissel, 2 lanes to 4.
151	Hillcrest Ave: E. 18 St to SR 4, 2 lanes to 4 with SPRR grade separation
155	John Muir Parkway: San Pablo Ave grade separation for J. Muir to EB SR 4, and J. Muir to WB I-80.
168	Meadow Ln: Monument to Market, 2 lanes to 6.
169	Meadow Ln: Market to Diamond, 0 lanes to 6.
170	Moeser Ln: San Pablo Ave to Carlson, 0 to 4 lanes.
173	Monument Boulevard: Buskirk Ave to Cowell Rd. Widen from 4 to 6 lanes.
176	Ninth St/Tenth St: O St to A St, convert to one-way couplet, 9th St WB and 10th St EB.
180	N. Main St: Oak Park to Contra Costa, 2 lanes to 4.

ID	Project Description
181	N. Parkside Dr: Willow Pass to Railroad Ave, 2 lanes to 4.
192	Olympic Blvd: Tice Valley Rd to Pleasant Hill Rd, 2 lanes to 4.
193	Pacheco/Jones/Pine/Court: Marina Vista to Shell, 2 lanes to 4.
194	Pacheco Blvd: Morello to Arthur, 2 lanes to 4.
195	Pacheco Blvd: Arthur to Blum, 2 lanes to 4 and replace ATSF grade separation.
196	Parkside Dr: Buena Vista to N Main, 2 lanes to 4.
197	Parr Blvd: Garden Tract to SPRR, 2 lanes to 4.
198	Pine Valley Rd: San Ramon Valley Blvd to Norris Cyn, 0 lanes to 2.
200	Pittsburg Ave: Garden Tract to 3rd St, 2 lanes to 4.
201	Pittsburg-Antioch Hwy: Loveridge to Sommersville, 2 to 4 lanes.
203	Port Chicago Hwy: Weapons Sta. entrance to Bates, 2 lanes to 4.
204	Port Chicago Hwy: SR 4 to N. 6th, 2 lanes to 4.
205	Port Chicago Hwy: N. 6th to Bonifacio, 2 lanes to 4.
206	Railroad Ave: Bliss to Buchanan, 4 lanes to 6.
207	Range Rd: Willow Pass to Wedgewood, 0 lanes to 2 with SR 4 interchange.
213	San Pablo Ave: Hercules Ave to J. Muir Pkwy, 4 lanes to 6.
220	Southern Pacific ROW: SR 4 to Concord Ave, construct 4 lane road via Commerce Ave.
61	Standard Oil Ave: Buchanan to E. Leland, 0 lanes to 4 with SR 4 interchange (4 lane U.C.).
221	Stone Valley Rd: I-680 to Miranda, 2 to 4 lanes.
222	Sunset Dr: Hillcrest to realigned SR 4 (along SPRR), 0 lanes to 2.

ID	Project Description
227	Third St: City limit to Parr, 2 lanes to 4.
229	Treat Blvd: Clayton to San Miguel, 4 lanes to 6.
230	Treat Blvd: Bancroft to Jones, 3 lanes to 4 WB for SB right turn at Bancroft.
236	Vine Hill Way: Morello to Alhambra Ave, 2 lanes 4.
238	Waterbird Way: Acme land fill to Imhoff, 0 lanes to 4 with ATSF grade separation.
240B	West Leland Rd: Willow Pass East to Willow Pass West, 2 to 4 lanes
242	Wilbur Ave: Widen SR 160 overpass, 2 to 4 lanes
246	Willow Pass Rd: No. Parkside to n/o ATSFRR, 2 lanes to 4.
247	Willow Pass Rd/10th St: N/o ATSFRR to Railroad, 2/4 lanes to 4.
241	Wilbur Ave: A St to SR 160, 2 lanes to 4.

APPENDIX E

TRANSPORTATION MODEL TECHNICAL ANALYSIS

ESTIMATION AND DEVELOPMENT OF THE TRIP GENERATION MODELS FOR CONTRA COSTA COUNTY GENERAL PLAN REVIEW PROGRAM

Prepared For:

The County of Contra Costa, California

Prepared By:

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August 1987

1.

INTRODUCTION

The first model of the travel demand modeling chain is the trip generation model. This model relates the origins and destinations of trips to land use and socio-economic characteristics of the county. The trip generation model developed for the County is based upon a home interview of nearly 5,000 households surveyed throughout the San Francisco Bay Area Region in 1981 by the Metropolitan Transportation Commission.

The trip generation model presented here focuses on travel generated and attracted to Contra Costa County. The model does not estimate travel by non-residents of the region, nor does it estimate commercial vehicle travel, e.g., trucks and taxis.

MODEL STRUCTURE

The trip generation model developed in this study estimates trip productions and trip attractions. The definition of a trip production is the home end of a trip, while a trip attraction is the non-home end of a trip. For example, if a person made two trips in a day, one from home to work and one from work to home, these two trips would have two productions, at the person's home, and two attractions, at the person's work place. Although these definitions are essentially artificial, they allow travel demand models to be structured in such a way as to relate trip ends to logical and reasonable socio-economic and land use characteristics.[1] For example, productions (i.e., home end trip ends) can be associatedwith the socio-economic characteristics of a household or a person, such as income, family size, automobiles available, age, lifestyle, etc.; while attractions can be associated with land use characteristics such as the amount of employment, type of employment, acres of land use type, school enrollment, etc. For this study, standard definition of trip productions and attractions will be maintained.

A second essential definition, in the design of a travel demand model structure, is the definition of the purpose of a trip. Any person or family makes trips for a multitude of purposes, and it is possible to stratify trips very precisely by their purpose, e.g., to visit relatives, visit friends, go to the doctor, go to the dentist, grocery shopping, shopping for furniture, etc. This type of precise, detailed definition would impose an undue burden upon the analysts and forecasters due to the proliferation of models and types of data which would have to be calibrated and analyzed. Most urban areas attempt to define a relatively small set of purpose definitions which, when combined, represent all types of travel. For this trip generation model, the universe of travel has been stratified into six purpose definitions, which are as follows:

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1 This applies not only to trip generation equations but also to distribution and mode choice models. For this reason, most model structures maintain the production/attraction format up to the assignment process.

1. Home-Based Work: All travel made for the purpose of work and which begins or ends at the traveler's home. This is a typical trip purpose with obvious relationships with total employment and the income of the person or household.

2. Home-Based Shopping (Other): Trips made for any type of shopping or personal business, with one end of the trip being at the traveler's home. Again, this trip purpose has obvious relationships to socio-economic and land use data; i.e., retail employment, income, and family size.

3. Home-Based Secondary School: Most urban areas will use the single school trip purpose. It was decided for this study to "split" school trips into travel to universities and travel to other schools, e.g., elementary and high schools. This decision was made for two reasons. First, university travel is different from secondary school travel with respect to distribution and mode choice, since the age of the traveler is different and there are fewer universities then secondary schools. Second, land use data (primarily enrollment) was available for universities and could be forecasted, while the data for secondary schools would have been difficult to obtain and to forecast. This purpose can be defined as any school trip made to an elementary or high school with one end being at the home.

4. Home-Based Diablo Valley College: Any school trip made to Diablo Valley College with one end of the trip being at home.

5. Home-Based Social/Recreational: Any trip made with one end at the home, except for the purpose of work, shopping, personal business, or school. This could include trips made for social visits, recreational trips, and restaurant trips.

6. Non-Home-Based: Any trip which neither begins nor ends at home. This category is essentially a trip where the "true" purpose of the trip could be work, shopping, school, or other. Allocating non-home-based trips to their true purpose is almost never done in a modeling effort since in forecasting these trips there is no way to associate the trip with a person's or household's socio-economic characteristics.

In the calibration of the travel demand models, the purpose of the surveyed trips was ascertained by asking the traveler the purpose of the trip and the origin and destination of the trip. The home interview survey did not ask sufficient questions pertaining to the precise school purpose definition, i.e., secondary or university trip, and this categorizaton was performed by ascertaining the location of the non-home end of the school trip, e.g., if the non-home zone was a zone containing Diablo Valley College, the school trip was defined as a university school trip.

Given these definitions, the trip generation model structure could be developed. The trip production model was stratified into six sub-models, one for each purpose, and the productions were related to the socio-economic characteristics of a household. The dependent variable (the unknown value to be forecasted) was trips per household. The primary postulated independent variables (the values which explain or affect the independent variable value) were the income of the household and the number of people residing in the household. Previous studies have shown that income and

household size are directly related to the number of trips generated by a household and can "explain" most of the reasons for changes in trip-making rates. Other studies have used socio-economic data such as age, automobiles available, and life style; but these variables were either not available or were not going to be forecasted for the County.

In order to make the maximum use of the information provided by the independent variables (income and family size) in explaining trip generation, it was decided to use disaggregate values instead of aggregate values. That is, the models would be calibrated and applied for each discrete group of households in a zone, rather than for all households in a zone, using average family size or income values. Although this type of technique will substantially improve the trip generation models, it does impose the difficulty of estimating households by discrete groups, e.g., the number of households in a zone with an income of less than $7,500 and only one person. In order to overcome this difficulty, the 1980 census was used to construct a model which will forecast these discrete groups, given average values (average income and persons per household) for the zone.

The home interview survey allowed the trip production model to be calibrated at its most disaggregate level, the household. Unfortunately, the trip attractive equations could not be calibrated at a disaggregate level but had to be calibrated at a more aggregate level. While the major independent variables for the production models, income and family size, are directly connected to total household trip making, through the home interview, the major independent variables for the attraction model, primarily employment, are only partially connected to the surveyed trips, i.e., only a small portion of the trips to any major generators were obtained in the home interview survey. The trip attraction models could therefore not be calibrated using disaggregate calibration techniques, such as cross-classification, and instead, more aggregate calibration techniques were required. The technique chosen for this study was linear regression, a fairly common calibration methodology for trip generation. The level of aggregation used for the attraction models was the district.[2] Since the trips produced by the surveyed households had to be compared to non-household characteristics, e.g., employment, it was necessary to estimate the total average daily travel, by purpose, from the home interview data.

This methodology is called expansion and is performed by comparing the total number of households to the number of households surveyed, usually by zone. For example, if 10 households were surveyed in a zone with 100 households, the total estimated daily trips from this zone would be calculated by multiplying the surveyed trips by 10.0 (100 households divided by 10 surveyed households); the factor is usually called an expansion factor. It was judged that zone level aggregation would not be sufficient for the calibration, and therefore the next level of aggregation, the district, was chosen. The explanatory (independent) variables chosen for consideration in the trip attraction models were: (1) total employment; (2) retail employment; (3) service employment; (4) other employment; (5) number of households; (6) population; and (7) Diablo Valley College student enrollment.

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[2] A district is a spatial measure consisting of an aggregation of traffic analysis zones. In this study, the individual zones were grouped into 20 geographical locations.

In summary, the trip generation model structure consists of:

1. A model to estimate households by income group and household size, given total households, average income, and average persons per household. This model was calibrated using the 1980 census data and will be applied at the traffic analysis zone level.

2. A set of models to estimate trip productions. This model uses income and household size as the primary independent variables. The model was calibrated at the household level and will be applied at the traffic analysis zone level. Cross-classification was the major calibration technique.

3. A set of models to estimate trip attractions. This model uses total employment, retail employment, service employment, other employment, households, population, and university student enrollment as the primary independent variables. The model was calibrated at the district level and will be applied at the traffic analysis zone level. Linear regression was the major calibration technique.

INCOME AND HOUSEHOLD SIZE MODEL

Introduction

The County transportation modeling system will use household size and income as the primary independent variables in the estimation of trip productions. These variables will be disaggregate in the calibration and application of the trip generation models. As a result, it will be necessary to estimate for each zone the number of households by income group and the number of persons per household by individual household size category. At present, average persons per household and average income can be forecasted, but not at the disaggregate level required by the trip generation model.

It has been ascertained, though, in other studies that the "mix" of disaggregate households is fairly similar for any spatial group, given the average values. In order to explore this relationship, the 1980 census and home interview data were obtained and summarized at the regional level. The data was plotted and it was found that a stable relationship between average values and disaggregate values could be developed for the County. By using this relationship and the forecasted average values, it will be possible to estimate disaggregate households with an excellent degree of accuracy.

The entire disaggregate household model consists of three sub-models. One sub-model relates the average person per household to disaggregate households by family size. The second sub-model relates average household income to households disaggregated into four income groups. The final sub-model is a technique which uses the results of the first two sub-models to estimate households disaggregated by income and persons per household.

The Disaggregate Household Size Model

The hypothesis for the disaggregate household size model is that for any given average household (i.e., persons per household), there is a specific "mix" of households for each

integer household size, i.e., one person per household, two persons per household, etc. In order to implement this hypothesis to obtain a functional model, the household data from the 1980 census was summarized and grouped by average household size. This summarizaiton was performed at the regional zone level and the data was grouped by ranges of 0.1 persons per dwelling unit, e.g., 1.45 to 1.55. The summarized data was plotted, and these plots showed a reasonable relationship between average household size and the distribution of the integer persons per household.

A preliminary model was developed by "hand-fitting" curves,[3] using the data. These non-linear hand-fitting curves, though, were not an adequate model since the percent of integer households did not necessarily meet two essential criteria. These two criteria were:

1. That the sum of the integer household's percent equal 100.0, and

2. That the calculated average persons per household, from the integrer household's percents, equal the average household size being used as the independent variable.

Each average household size range was investigated to ascertain the change required in the integer household size percents in order to meet the two constraining criteria. The curves were then redrawn and smoothed to produce a useable model for disaggregate household size distribution. The final model is shown on Figure 1 and Table 1.

The Disaggregate Household Income Model

As with household size, it was hypothesized that the "mix" of households by income groups, or ranges, can be estimated, given the average income of the households. Prior to beginning the analysis for this model, it was necessary to define the income grups or income ranges. The home interview survey had obtained information by 15 income groups, and an analysis of 1980 census showed that groups were compatible with the 1980 census data. Four income groupings from the home interview were used for this model and for the subsequent trip production analysis. The income group definitions are as follows:

Group	($ 1980) Income Range	Percent of Households In Group
1	less than 15,000	31.59
2	15,001 to 25,000	24.65
3	25,001 to 35,000	20.80
4	35,001 and above	22.96

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[3]The plot was of average household size versus the percent of households for each integer size.

TABLE 1

HOUSEHOLD SIZE DISTRIBUTION MODEL

Avg. Household Size (Persons per Household)	Percent of Households With: 1 Person	2 Persons	3 Persons	4 Persons	5 Persons	6+ Persons
1.3	69.0	31.0	0.0	0.0	0.0	0.0
1.4	60.0	39.8	0.2	0.0	0.0	0.0
1.5	50.0	49.1	0.7	0.2	0.0	0.0
1.6	44.5	51.1	3.0	1.2	0.2	0.0
1.7	41.0	50.7	5.1	2.4	0.7	0.1
1.8	38.5	49.1	7.1	3.6	1.3	0.4
1.9	36.0	48.1	8.4	5.1	1.6	0.8
2.0	33.2	46.6	10.2	6.3	2.5	1.2
2.1	31.2	45.4	11.7	7.3	2.8	1.6
2.2	29.0	44.1	13.1	8.3	3.3	2.2
2.3	26.7	43.4	14.2	9.4	3.7	2.6
2.4	25.0	41.4	15.2	10.6	4.6	3.2
2.5	23.6	39.5	16.2	11.8	5.3	3.6
2.6	22.0	37.5	17.3	12.9	6.2	4.1
2.7	20.5	35.3	18.3	14.1	7.0	4.8
2.8	19.0	33.6	18.8	15.4	7.9	5.3
2.9	17.5	31.5	19.6	16.7	8.7	6.0
3.0	16.0	29.7	19.9	17.9	9.6	6.9
3.1	14.8	28.1	20.2	19.1	10.3	7.5
3.2	13.2	27.1	20.3	20.4	10.8	8.2
3.3	12.1	25.6	20.4	21.5	11.3	9.1
3.4	11.2	23.9	20.3	22.4	11.9	10.3
3.5	10.3	22.2	20.2	23.2	12.5	11.6
3.6	9.4	21.0	19.9	23.7	13.0	13.0
3.7	8.5	19.5	19.6	24.3	13.5	14.6
3.8	7.7	18.4	19.2	24.6	13.9	16.2
3.9	6.9	17.6	18.6	24.8	14.2	17.9
4.0	6.1	16.6	17.9	25.0	14.3	20.1
4.1	5.6	15.8	16.7	25.1	14.5	24.6
4.2	5.1	14.7	15.9	25.2	14.5	24.6
4.3	4.8	13.9	14.9	25.0	14.5	26.9
4.4	4.2	13.1	14.2	24.9	14.4	29.2
4.5	4.0	12.2	13.5	24.8	14.3	31.2
4.6	3.7	11.5	12.6	24.6	14.0	33.6
4.7	3.3	10.7	11.7	24.4	13.7	36.2
4.8	3.1	10.0	10.7	24.0	13.3	38.9
4.9	3.0	9.3	10.0	23.4	12.7	41.6
5.0	2.9	8.7	9.4	22.6	11.9	44.5

Note: Average family size for the 6+ strata is 6.79.

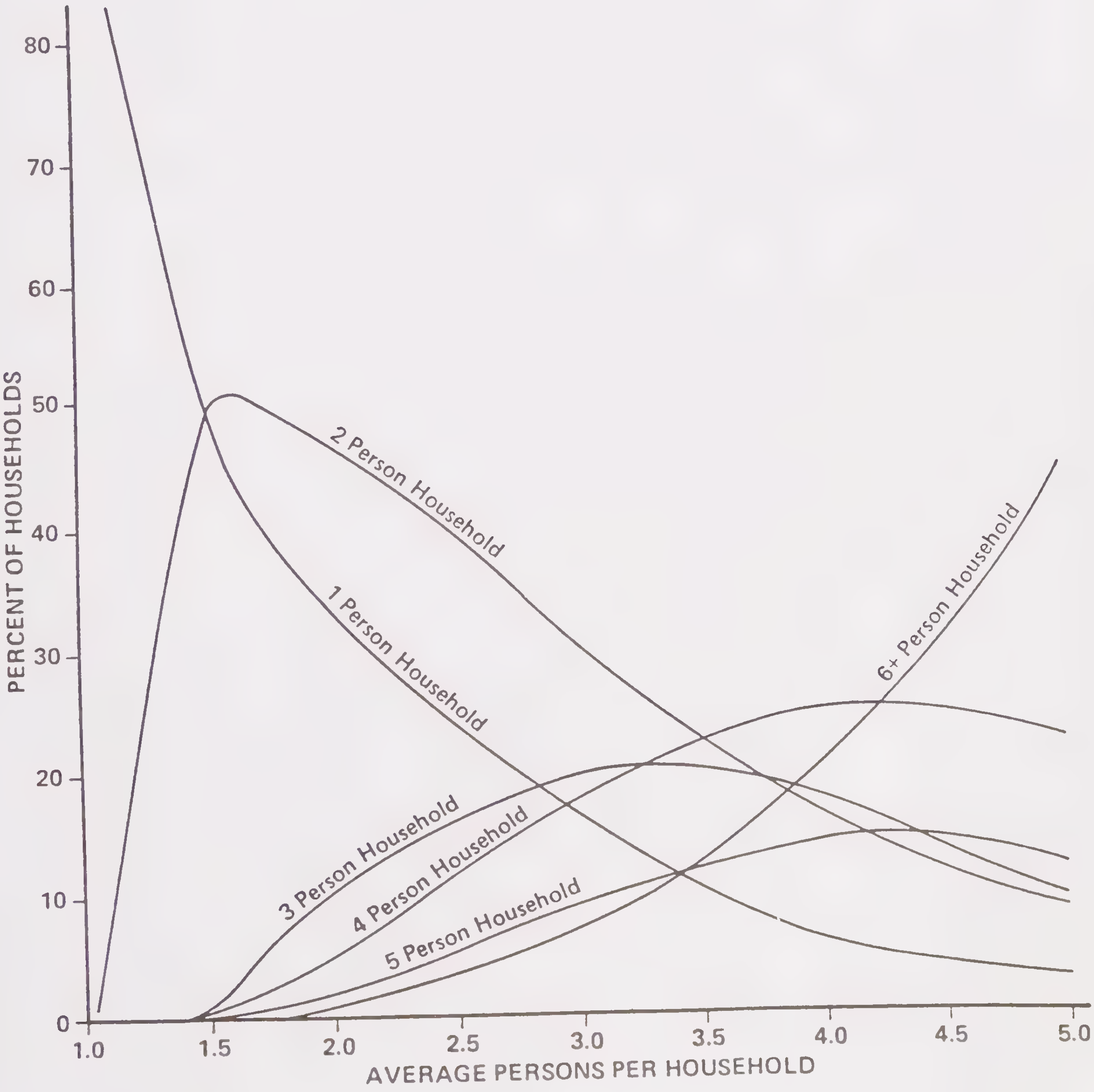

Figure-1

DISTRIBUTION OF HOUSEHOLD SIZE AS A FUNCTION OF AVERAGE PERSONS PER HOUSEHOLD

Barton-Aschman Associates, Inc.

These groups were related to the average income of the zone, or more precisely, to the average income of the zone divided by the regional average income (Income Index). For the calibration effort, the use of average income, or Income Index, is irrelevant since the only effect is to modify the scale of the independent variable, i.e., average income. For the forecasts, the use of the Income Index will simplify the application effort since it will not be necessary to adjust forecasted incomes to account for inflation. As with the household model, the 1980 census data was summarized by ranges of the independent variable (Income Index); in this case, by 0.1 Income Index ranges. The summarized data was plotted, and these plots showed a reasonable relationship between the Income Index and the distribution of households by the four income groups. A model was developed by "hand-fitting" curves using the census data and the constraint that the sum of the percent of households for each Income Index value must equal 100. The final model is shown on Table 2 and Figure 2.

TABLE 2

HOUSEHOLD INCOME DISTRIBUTION MODEL

Percent of Households in Each Income Group

Income Ratio	Income Group 1	Income Group 2	Income Group 3	Income Group 4
.1	100.00	0.00	0.00	0.00
.2	93.25	5.50	1.25	0.00
.3	82.35	12.80	3.40	1.45
.4	73.00	18.60	5.20	3.20
.5	63.70	23.00	8.10	5.20
.6	55.00	26.50	10.90	7.60
.7	46.00	28.25	15.25	10.50
.8	37.50	28.50	20.00	14.00
.9	31.25	27.75	22.50	18.50
1.0	25.75	26.25	24.50	23.50
1.1	22.50	24.50	23.50	29.50
1.2	19.50	22.00	23.00	35.50
1.3	17.00	20.50	22.00	40.50
1.4	15.00	18.60	21.50	44.90
1.5	14.00	17.00	20.00	49.00
1.6	13.00	16.00	18.75	52.25
1.7	12.25	14.00	17.50	56.25
1.8	11.75	13.00	16.25	59.00
1.9	11.40	12.00	15.25	61.35
2.0	11.00	11.25	14.40	63.35
2.1	10.80	10.75	13.60	64.85
2.2	10.60	10.40	13.00	66.00
2.3	10.50	10.10	12.60	66.80
2.4	10.50	10.10	12.50	66.90
2.5	10.50	10.10	12.50	66.90

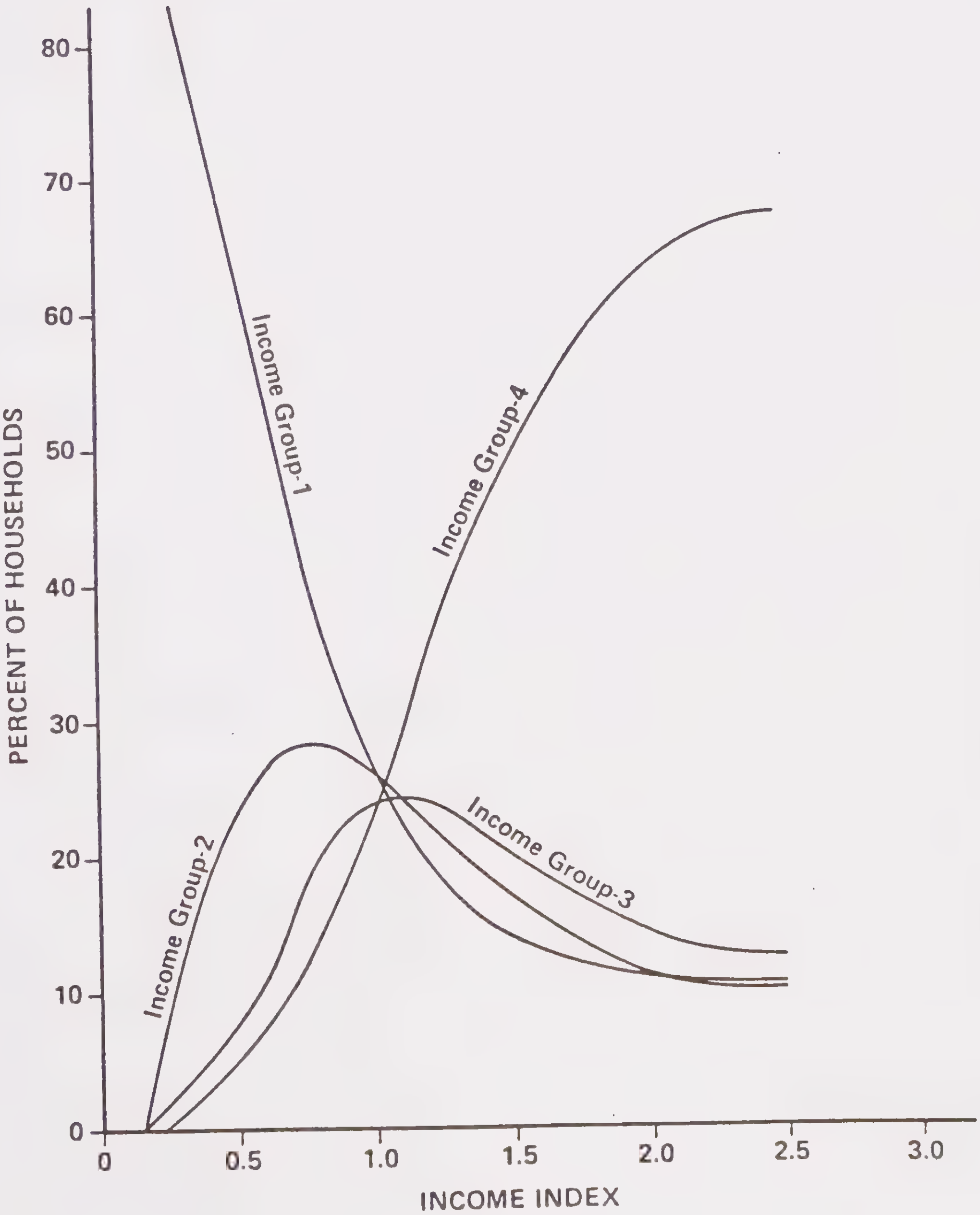

Figure-2

RELATIONSHIP OF INCOME GROUPS TO AVERAGE INCOME

Barton-Aschman Associates, Inc.

Estimating Disaggregate Households by Income and Persons Per Household

The first two sub-models will allow for the forecast of disaggregate households by income group and household size separately. The final sub-model completes this disggregation by using the first two sub-models and additional data to estimate disaggregate households by each combination of income group and household size. In order to implement this sub-model, it was necessary to determine the percent of households by the 24 strata of income groups/household size. This stratification is shown on Table 3. This data was then reduced to obtain the percent of households by income group and size strata. The technique to perform this estimation is as follows:

1. Estimate households by income group using disaggregate household income group model.

2. Estimate households by household size using disaggregate household size model.

3. Use percent of households from Table 4 and households by household size to estimate households by income group and household size.

4. Compare estimate households by income group from step 3 with households from step 1. If any income group total is incorrect, balance matrix so that households by income group equal step 1 estimate.

The balancing technique used in step 4 is an algorithm which will maintain the estimates from step 1 and 2 while modifying the matrix topology as little as possible. In applying this model, the four-step procedure would be applied for each traffic analysis zone. Normally the regional percent of households in each income group is constrained to the percents determined in the base year. The four-step procedure applied for each zone does not guarantee that the base year regional percents will be maintained, and therefore, the last step in the sub-mode procedure is to "normalize" the households by income groups from the four-step procedures so that the regional percents are correct.

TRIP PRODUCTION MODEL

The trip production model consists of six cross-classification sub-models, one for each trip purpose. The data from the home interview survey for Contra Costa County residents was summarized by income group and persons per household strata. This reduced data was then statistically analyzed to ascertain the most appropriate cross-classification model for each trip purpose.

The calibration file for the trip production model consisted of socio-economic and travel data for 425 Contra Costa County households from the home-interview survey. A summary of these households, stratified by income group and household size, is shown on Table 5. The County distribution of the surveyed households by income group

TABLE 3

PERCENT OF HOUSEHOLDS STRATIFIED BY INCOME GROUP AND PERSONS PER HOUSEHOLD

Persons per Household	Percent of Households in: Income Group 1	Income Group 2	Income Group 3	Income Group 4	Total
1	13.71	7.88	2.98	2.02	26.59
2	9.55	7.80	7.10	8.79	33.24
3	3.97	3.95	3.87	4.54	16.33
4	2.24	2.74	4.33	4.78	14.09
5	1.15	1.31	1.57	1.91	5.95
6+	0.97	0.97	0.95	0.93	3.81
TOTAL	31.59	24.65	20.80	22.96	100.00

TABLE 4

PERCENT OF HOUSEHOLDS IN EACH INCOME GROUP STRATIFIED BY PERSONS PER HOUSEHOLD

Persons per Household	Percent of Households in: Income Group 1	Income Group 2	Income Group 3	Income Group 4	Total
1	51.55	29.64	11.22	7.59	100.00
2	28.74	23.47	21.35	26.44	100.00
3	24.32	24.20	23.70	27.78	100.00
4	15.88	19.46	30.76	33.90	100.00
5	19.32	22.03	26.44	32.21	100.00
6	25.40	25.40	24.87	24.33	100.00

TABLE 5

SUMMARY OF HOUSEHOLDS STRATIFIED BY INCOME GROUP AND HOUSEHOLD SIZE

Total Survey Households

Persons per Household	Income Group 1	2	3	4	Total
1	40	19	9	6	74
2	40	30	39	35	144
3	12	15	24	26	77
4	10	19	21	32	81
5	7	4	10	13	34
Greater than 6	3	1	5	6	15
TOTAL	112	87	108	113	425

and household size was compared with the regional distribution. Overall, the distributions compared quite well, as shown below:

Income Group	Percent of Households by Income Group: Regional	County	Persons Per Household	Percent of Households by Household Size: Regional	County
1	31.59	26.35	1	26.59	17.41
2	24.65	20.47	2	33.24	33.88
3	20.80	25.41	3	16.33	18.12
4	22.96	27.77	4	14.09	19.06
			5	5.95	8.00
			6+	3.81	3.53

This rather close comparison of the two distributions lends credence to the fact that the home interview within Contra Costa County was a random sample of the households.

The home interview data showed that the average household generate approximately 9.8 trips. There is a considerable variance in this rate, though, when stratified by income group or household size. The number of total trips per household increases substantially as income increased or as household size increases, as shown below:

Income Group	Total	Persons per Household	Total
1	6.366	1	3.892
2	8.023	2	7.243
3	11.278	3	10.026
4	13.119	4	14.259
		5+	18.755
	9.828		9.828

To ascertain if the County-level surveyed trip rates were reasonable, they were compared with data from the overall San Francisco Bay region. The County's total trips per household was only 12 percent higher than the regions with a similar pattern by household size, as shown below:

Persons Per Household	San Francisco Bay Area[4] Trips/Household for: 1965	1981	Contra Costa County
1	3.35	3.953	3.892
2	6.169	7.079	7.243
3	8.443	9.646	10.026
4	11.309	13.533	14.259
5+	15.22	17.717	18.755
Total	8.778	8.713	9.828

[4]Information from "Changes in Regional Travel Characteristics in the San Francisco Bay Area: 1960-1981," by Hanna P. H. Kollo and Charles L. Pervis, August 1983.

A review of the trip rates by purpose showed reasonable results also. Work trips acount for about one-fifth of all trips, and school trips consist of nearly 10 percent of all trips.

Purpose	Trips per Household for: Bay Area	Contra Costa County
Work	1.890	1.889
Shop/Other	2.274	2.671
Social/Recreational	1.262	1.016
School	0.952	1.016
NHB	2.335	2.922
TOTAL	8.713	9.828

The purpose distribution was compared with the regional data and there was substantial agreement between these data sets, as shown below:

	Percent of Total Trips for:		
	San Francisco Bay 'rea		
Purpose	1965	1981	Contra Costa
Work	24.25	23.64	19.23
Shop	33.39	27.46	27.17
Other	13.26	14.15	13.53
School	7.35	8.07	10.34
NHB	21.75	26.67	29.73

A detailed summary of trip rates for the County is shown on Tables 6 and 7.

Home Based Work Production Model

The home based work trips were stratified by income group and household size, and the average trip rate (trips per household) was calculated for each strata. This information is presented in Table 8. In general, the trip rate incrases as income increases and household size increases. In order to ascertain the range of observed values in each strata, the standard error[5] of the sample was calculated, and this

[5] The standard error of the mean is a statistical calculation which can be interpreted as follows: given a normal distribution, 68 percent of the observations will be within one standard error of the average value and 95 percent will be within two standard errors of the average value.

TABLE 6

SUMMARY OF TRIP RATES BY INCOME GROUP

Income Group	Trip Purpose: Home-Based Trips: Work	Shop/Other	Social/ Recreational	School	Non-Home Based
1	0.813	2.321	0.920	0.705	1.607
2	1.632	2.230	1.138	0.575	2.448
3	2.343	3.083	1.556	1.204	3.093
4	2.686	2.949	1.653	1.466	4.364
TOTAL	1.889	2.671	1.329	1.016	2.922

TABLE 7

SUMMARY OF TRIP RATES BY HOUSEHOLD SIZE

Trips per Household by Persons per Household

Income Group	Trip Purpose: Home Based Trips: Work	Shop/Other	Social/ Recreational	School	Non-Home Based
1	0.838	0.973	0.459	0.054	1.567
2	1.576	1.903	1.132	0.125	2.507
3	2.390	2.584	1.338	0.740	2.974
4	2.346	3.963	1.815	1.975	4.160
5+	2.857	5.490	2.408	3.939	4.061
TOTAL	1.889	2.671	1.329	1.016	2.922

TABLE 8

SUMMARY OF HOME-BASED WORK TRIPS

Home-Based Work Trips per Household

Persons per Household	Household Income Group 1	Group 2	Group 3	Group 4
1	0.450	1.211	1.444	1.333
2	0.650	1.800	1.792	2.200
3	1.000	1.933	2.375	3.308
4	1.200	1.222	2.714	3.094
5	2.429	2.500	3.400	1.769
6+	2.000	4.000	4.400	4.000

Standard Error[6] of the Mean
Home-Based Work Trip Productions

Persons per Household	Household Income Group 1	Group 2	Group 3	Group 4
1	0.143	0.196	0.412	0.494
2	0.225	0.316	0.247	0.245
3	0.461	0.358	0.385	0.379
4	0.629	0.286	0.391	0.289
5	0.751	0.289	0.897	0.469
6+	0.000	0.000	1.166	0.730

[6] Standard error of the mean is the standard deviation divided by the square root ofthe observations (households).

information is shown on Table 8. For those strata with a substantial number of observations (more than 30 households), the standard error to the mean is normally less than 30 percent of the average trip rate. For smaller samples, the standard error can be as high as 100 percent of the average trip rate. The use of the satistical measures such as standard deviation allowed for the comparison of adjacent trip rates to ascertain if the trip rates could be considered to be the same. Specifically, this statistical test is called the Student t test between means. This testing was necessary if some of the strata were to be combined, and given the small number of observations in some strata, this was important to obtain stable trip rates. The technique used was to test adjacent income group trip rates, holding the household size constant, and test adjacent household size trip rates, holding the income groups constant. The initial t tests performed on the home-based work trip rates are shown on Table 9. For the income comparison, there were several size-income strata which were not significant[7], but were was at least one household size strata which contained a significant difference in the average trip rate for each income group comparison. For this reason, no income groups were combined in the final cross-classification model. For the household size comparison, there were no income strata which had significant t test values for the comparison between three persons per household and four persons per household. Only one income strata showed significance for the five to six plus person per household comparison, and the number of underlying observations was extremely minimal. Given the results of those tests, it was decided to combine household sizes 3 and 4, and 5 and 6 or more for the final cross-classification model shown in Table 10.

Home-Based Shop/Other Model

Home-based shopping trips were, as with work trips, stratified by income and household size. The average trip rate and standard error of the mean for these strata are shown on Table 11. The application of the t test to household size showed that two to three and four persons per household could be combined, as well as five or six or more persons per household. The t test for income groups showed that income has a very minor effect on the shopping trip rate. The home-based shopping cross-classification model is shown on Table 12.

Home-Based Social/Recreational Model

The home-based social/recreational trips were also stratified by income group and household size. A summary of the trip rates and standard error of the mean is shown on Table 13. Compared with shopping trips, the trip rate did not vary by income group. The t tests showed that income groups could not be combined, with the exception of gruops two and three. There were substantial differences in trip rates by family size, and only five and six persons per household could be combined. The final cross-classification model for home-based other productions is shown in Table 14.

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[7] A significant T test means that the two trip rates could not be considered the same at the 5 or 1 percent confidence limit.

TABLE 9

COMPARISON OF MEANS TESTS FOR HOME-BASED WORK TRIPS

t Test on Income

Persons per Household	Income Groups Compared		
	Group 1 to 2	Group 2 to 3	Group 3 to 4
1	3.070**	0.585	0.172
2	3.048**	0.013	1.160
3	1.626	0.783	1.725*
4	0.037	2.989**	0.796
5	0.069	0.615	1.720*
6+	0.000	0.140	0.302

t Test on Persons per Household

Income Group	Person Per Household Strata Compared				
	1 to 2	2 to 3	3 to 4	4 to 5	5 to 6+
1	0.750	0.727	0.262	1.254	0.361
2	1.379	0.259	1.570	2.023*	2.325
3	0.635	1.332	0.616	0.822	0.660
4	1.379	2.557**	0.457	2.441**	2.627**

* Significant at the 5% level
** Significant at the 1% level

Note: t Test based on separate variance estimates

TABLE 10

HOME-BASED CROSS-CLASSIFICATION MODEL

Work Productions Per Household

Persons per Household	Income Group 1	2	3	4
1	0.450	1.211	1.444	1.333
2	0.650	1.800	1.792	2.200
3 and 4	1.090	1.545	2.073	3.190
5 and greater	2.300	2.800	3.733	3.353

Table 11

SUMMARY OF HOME-BASED SHOPPING/OTHER TRIPS

Trips per Household

Persons per Household	Household Income			
	Group 1	Group 2	Group 3	Group 4
1	1.075	0.737	1.000	1.000
2	2.000	1.967	1.872	1.771
3	3.250	2.000	3.125	2.115
4	3.800	4.167	4.857	3.313
5	3.429	2.000	4.000	5.231
6+	12.000	8.000	6.800	8.500

Standard Error of the Mean

Persons per Household	Household Income			
	Group 1	Group 2	Group 3	Group 4
1	0.173	0.185	0.441	0.365
2	0.410	0.394	0.366	0.269
3	1.023	0.625	0.899	0.378
4	0.814	0.789	0.913	0.487
5	1.477	1.225	0.789	1.340
6+	5.774	0.000	3.072	1.857

TABLE 12

HOME-BASED SHOPPING/OTHER CROSS-CLASSIFICATION MODEL

Productions per Household

Persons per Household	Income Group			
	1	2	3	4
1	0.966	0.966	1.000	1.000
2, 3	2.140	2.140	2.140	2.140
4 & greater	4.538	4.538	4.538	4.538

TABLE 13

SUMMARY OF HOME-BASED SOCIAL/RECREATIONAL TRIPS

Trips per Household

Persons per Household	Household Income Group 1	Group 2	Group 3	Group 4
1	0.475	0.368	0.222	1.000
2	0.575	1.233	1.692	1.057
3	1.333	0.933	1.000	1.885
4	2.600	1.389	1.905	1.750
5	1.857	2.750	1.000	1.923
6+	2.000	5.000	5.200	3.667

Persons per Household	Standard Error of the Mean Household Income Group 1	Group 2	Group 3	Group 4
1	0.143	0.175	0.222	0.683
2	0.186	0.306	0.310	0.205
3	0.607	0.419	0.255	0.420
4	0.777	0.465	0.457	0.327
5	1.243	0.479	0.537	0.635
6+	1.155	0.000	2.478	1.282

TABLE 14

HOME-BASED SOCIAL/RECREATIONAL CROSS-CLASSIFICATION MODEL

Trip Productions per Household

Persons per Household	Income Group		
	Group 1	Groups 2 & 3	Group 4
1	0.475	0.441	0.441
2	0.575	1.138	1.138
3	1.338	1.338	1.338
4	1.815	1.815	1.815
5+	1.900	2.538	2.538

Home-Based School Production Models

School trips for the trip generation analysis were stratified into two types of school trips: (1) school trips to Diablo Valley College (DVC), and (2) school trips to all other schools (i.e., secondary school trips). There were several reasons for this definition of school trips; primarily: (1) that there is a substantial difference in age between university students and secondary students; (2) that secondary students are very prevalent in the region and tend to "follow" population, while there are only a few universities/colleges, and these may not follow the population; and (3) university enrollment will be forecasted, while secondary school enrollment will not be.

Given this definition, the two types of school trips were stratified by income group and household size. The average trip rates and standard error of the mean for the two stratification are shown on Tables 15 and 16.

For secondary school trips, the income of the household had a fairly minor effect, while trip rate by house size varied substantially. The cross-classification model for school trips is shown on Table 17.

For DVC productions, income tended to be more important than it was for school trips. The household size strata was found to be able to be combined into only two

TABLE 15

SUMMARY OF HOME-BASED SCHOOL TRIPS

Trips per Household

Persons per Household	Household Income Group 1	Group 2	Group 3	Group 4
1	0.050	0.105	0.000	0.000
2	0.150	0.100	0.077	0.171
3	0.750	0.667	0.500	1.000
4	2.300	1.833	1.905	2.000
5	3.571	0.500	4.100	3.077
6+	4.667	0.000	6.800	6.167

Standard Error of the Mean

Trips per Household

Persons per Household	Household Income Group 1	Group 2	Group 3	Group 4
1	0.035	0.105	0.000	0.000
2	0.084	0.073	0.057	0.171
3	0.372	0.374	0.181	0.251
4	0.633	0.373	0.441	0.318
5	0.751	0.500	0.737	0.873
5+	2.403	0.000	0.583	1.138

TABLE 16

SUMMARY OF HOME-BASED DVC TRIPS

Trips per Household

Persons per Household	Group 1	Group 2	Group 3	Group 4
1	0.050	0.000	0.000	0.000
2	0.000	0.067	0.051	0.114
3	0.333	0.000	0.000	0.154
4	0.100	0.000	0.048	0.063
5	0.286	1.000	0.400	0.308
6+	0.000	0.000	0.000	0.000

Standard Error of the Mean
for Home-Based DVC Trips

Persons per Household	Income Group 1	Income Group 2	Income Group 3	Income Group 4
1	0.050	0.000	0.000	0.000
2	0.000	0.067	0.051	0.068
3	0.333	0.000	0.000	0.107
4	0.100	0.000	0.048	0.063
5	0.286	1.000	0.400	0.308
6+	0.000	0.000	0.000	0.000

TABLE 17

CROSS-CLASSIFICATION MODEL FOR SCHOOL TRIPS

Home-Based Secondary School Productions per Household

Persons per Household	Income Group		
	Group 1	Groups 2 & 3	Group 4
1 & 2	0.100	0.102	0.101
3	0.740	0.740	0.740
4+	1.975	1.975	1.975

Home-Based DVC Productions per Household

Persons per Household	Income Group	
	1 & 2	3 & 4
1 & 2	0.031	0.067
3, 4, 5 & 6+	0.157	0.102

categories: 1 and 2 persons per household and 3 or more persons per household. It may be possible that income and household size have a greater effect on university trips than this analysis indicated, but the smaller number of university school trips obtained by the home interview survey prohibited any finer level of detail than shown on Table 17, the cross-classification model for home-based DVC productions.

The DVC cross-classification model was applied to the household data set, and estimated DVC productions were calculated. The observed and estimated productions were then stratified by distance to DVC in one-mile increments. This compressed data set was then used to calibrate a model of the form:

$$OBS/EST = A * DIST^{B}$$

This model formulation is analogous to a gravity model formulation in that the probability of making a trip is inversely proportional to the distance (time) ofthe trip taken to a power. The model was calibrated using linear regression with each observation (i.e., one-mile strata) weighted by the number of observed trips. The equalition produced by this regression was:

$$OBS/EST = 4.63638 * \text{Distance}^{-0.75094}$$

The statistical tests for this model were significant with the coefficient of determination being 0.587. The final DVC trip production model is therefore as follows:

$$\text{DVC Trip Productions} = (\text{Estimated Trips from Cross-Classification Model}) * (\text{Distance}^{-0.75094})$$

This model can decrease the average trip rate quickly for the first five miles from DVC (See Figure 3), while trip rate changes after five miles are much more gradual. In order to minimize preparation time in computing this distance, all distances over 10 miles will be set to 10 miles. Also, the model shown above was constrained to produce the correct regional number of DVC trips as household location is a very significant variable in the model. For this reason, however, the DVC productions should be "normalized" to DVC attractions.

Non-Home-Based Production Models

Since non-home-based trips are associated with travel which neither begins nor ends at the traveler's home, a non-home-based production model is not essential to the travel demand process. This study, though, has developed a non-home-based production model in order to estimate a regional control total of non-home-based trips based on the socio-economic characteristics of residents of the area.

The non-home-based trip data was stratified in the same manner as the other trip purposes. A summary of this stratification is shown on Table 18. For single family households and households with six or more people, the income of the household had practically no effect on the genreation of non-home-based trips. It was also found that three- four-, five-, and and six-person households could be combined. The final non-home-based cross-classification model is shown on Table 19.

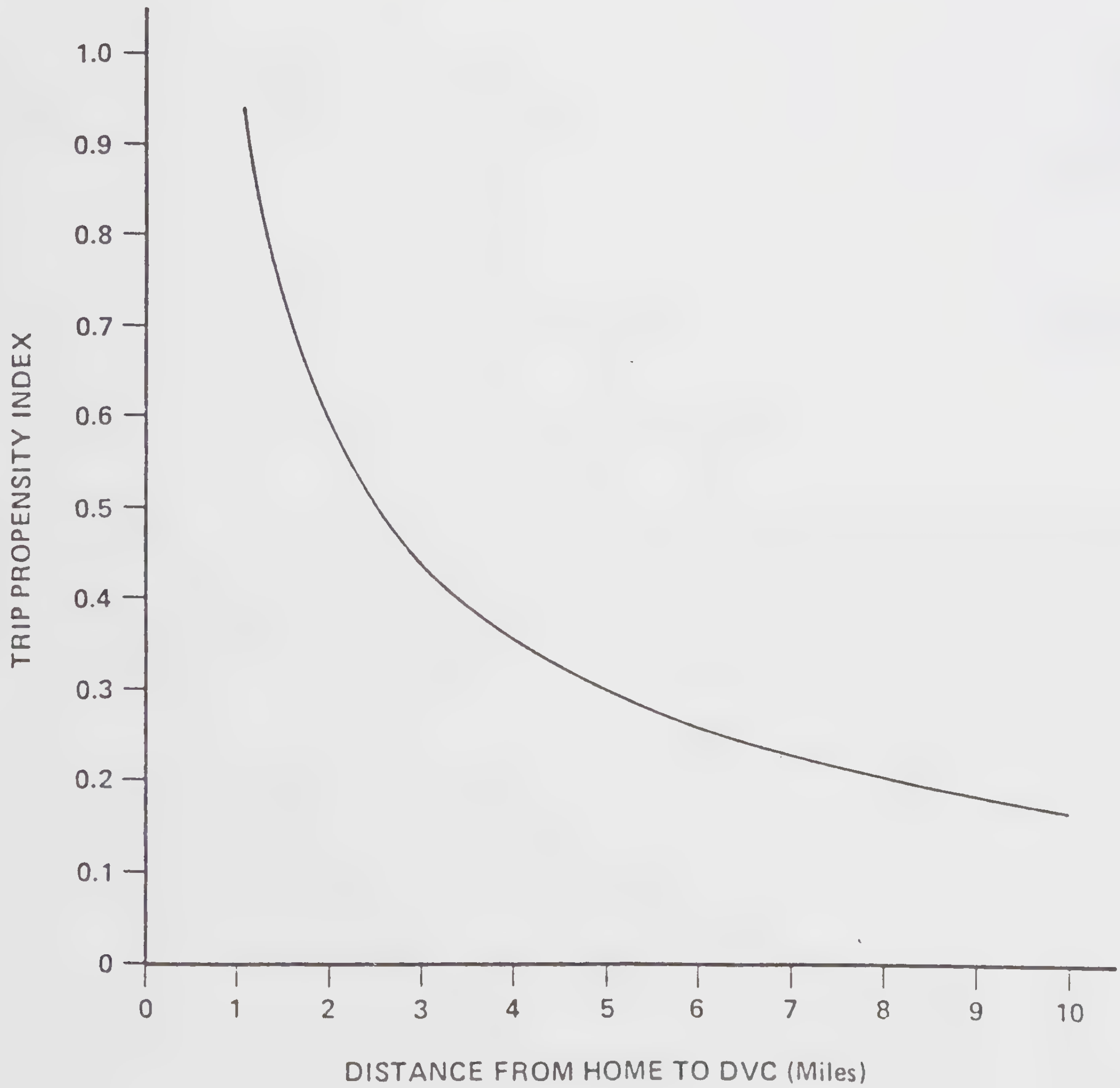

Figure-3

TRIP PROPENSITY INDEX FOR DVC TRIPS

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TABLE 18

SUMMARY OF NON-HOME-BASED TRIPS

Trips per Household

Persons per Household	Household Income Group 1	Group 2	Group 3	Group 4
1	1.225	2.053	1.444	2.500
2	1.425	2.167	2.872	3.629
3	2.500	1.667	3.250	3.692
4	2.300	3.500	3.571	5.500
5	1.857	2.750	2.900	3.308
6+	2.667	10.000	5.400	9.667

Standard Error of the Mean

Persons per Household	Household Income Group 1	Group 2	Group 3	Group 4
1	0.228	0.442	0.580	0.885
2	0.380	0.484	0.658	0.578
3	0.754	0.398	0.643	0.861
4	0.651	0.643	0.885	1.049
5	0.769	1.887	0.836	0.858
6+	1.667	0.000	2.112	1.308

TABLE 19

NON-HOME-BASED CROSS-CLASSIFICATION MODEL

Persons per Household	Non-Home-Based Trips per Household			
	1	2	3	4
1	1.225	1.971	1.972	1.971
2	1.425	2.167	2.872	3.629
3+	2.312	2.868	3.483	4.844

TRIP ATTRACTION MODEL

Introduction

The trip attraction model consists of five linear regression models, one for each purpose. The trip data from the MTC 1981 home interview survey was expanded to represent an average day of travel for the entire region. These expanded attractions were then compared statistically to land use data, using linear regression. This comparison was performed at a district level since large expansion factors prevented the determination of stable relationships at a smaller level of aggregation, e.g., a zone level.

The attraction model design was limited, as is normal, by the land use data which was available and would be forecasted. The following is a list of land use information which was considered:

- o Total Employment
- o Retail Employment
- o Service Employment
- o Other Employment
- o Population
- o Households
- o Diablo Valley College Enrollment

Regression Analysis

The district attractions were regressed against the basic logical land use variables, e.g., employment, population, households, and school enrollment. In all 18 linear regressions were performed. A summary of this analysis is shown on Table 20. In general, a linear equation was found for each trip purpose which produced a logical and statistically significant model.

TABLE 20

LIST OF EQUATIONS INVESTIGATED FOR ATTRACTION MODELS

	Equation	R^2	F-Value
Home-Based Work Attractions			
1.	1.605 * Total Employment	0.953	389.486
2.	2.764 * Other Employment + 3.403 * Retail Employment	0.890	77.326
Home-Based Shop/Other Attractions			
1.	4.280 * Retail Employment + 0.777 * Population - 0.454 * Total Employment	0.965	175.388
2.	5.553 * Retail Employment + 4.042 * Other Employment	0.872	64.997
3.	3.285 * Retail Employment - 0.979 * Other Employment + 0.803 * Population	0.963	166.966
4.	2.478 * Retail Employment + 1.998 * Households	0.957	211.886
5.	2.042 * Retail Employment + 1.055 * Service Employment - 2.884 * Other Employment + 2.639 * Households	0.962	121.575
Home-Based Social/Recreational Attractions			
1.	1.816 * Retail Employment + 0.145 * Service Employment + 0.346 * Population	0.995	134.657
2.	1.962 * Retail Employment + 0.350 * Population	0.957	213.207
3.	2.109 * Retail Employment - 0.049 * Total Employment + 0.356 * Population		

TABLE 20 (Continued)
LIST OF EQUATIONS INVESTIGATED FOR ATTRACTION MODELS

	Equation	R^2	F-Value
Home-Based School Attractions			
1.	0.345 * Population	0.871	127.794
2.	0.274 * Population + 0.191 * Households	0.864	60.690
Non-Home Based Attractions			
1.	5.636 * Retail Employment + 0.421 * Population	0.967	282.596
2.	0.694 * Other Employment + 5.258 * Retail Employment - 0.609 * Service Employment + 0.965 * Households	0.965	131.553
3.	5.630 * Retail Employment + 0.017 * Other Employment + 0.420 * Population	0.966	177.934
4.	5.462 * Retail Employment - 0.708 * Other Employment + 1.356 * Households	0.965	177.213
5.	6.816 * Retail Employment + 2.642 * Other Employment	0.936	140.563
6.	10.019 * Retail Employment	0.910	191.795

For home-based work trips, two equations were tested: one which used total employment and one which separated employment into retail and other employment. The two variable models, using retail and other employment, infer that retail employees made more work trips than other employees. This is a fairly illogical results, and therefore, the single variable model, i.e., total employment, was chosen for additional analysis. The coefficient of determination (R-squared) for this equation is substantial, being 0.953.

Five equations were investigated for home-based shopping/other attractions. All of the equations included retail employment, with up to three additional variables. In the equations which included households rather than population, the household variable is linearly related to population and would not, over time, reflect changing household size, and would not be as attractive as the population variable. In equation 2, the positive sign on the other employee variable is illogical, given the following:

1. Non-retail employees should not, by themselves, attract shopping trips.

2. Non-retail employees, though, will make some "non-motorized" shopping trips to retail establishments in the vicinity of their workplace.

3. Retail establishments do not judge their sales, and therefore their requirements for employment, on the basis of motorized trips attracted but on the basis of all trips attracted.

4. Therefore, the more non-retail employees there are in an area, the less the need is to attract motorized shopping trips (per retail employee).

The third equation was an attempt to increase the coefficient of determination. This equation added the population variable to the second equation. The statistical results from this equation were very good: the R-squared value increased to 0.96. The coefficient on retail employment decreased to 3.3, and the coefficient on other employment became negative. The coefficient on population was significant and positive. To have population as a variable in a shopping attraction model may appear illogical. The rationale why population is a significant variable in the equation is as follows:

1. There are a significant number of types of retail establishments which are essentially location-dependent, i.e., shoppers tend to go to the nearest establishment.

2. Thus the increase in shopping/other attractions when district population increases is simply an indication that retail establishments near population centers will attract more trips per employee than retail establishments which are not near population centers.

The home-based social/recreational purpose includes social trips, recreational trips, and other miscellaneous trip purposes which do not fall within the work, shopping/other, and school purpose definitions. It was therefore anticipated that most of the related land use variables would have some positive effect on generating home-based social/recreational attractions, including retail employment, other employment, population, and households. Three equations were explored in developing the home-based social/recreational model.

Only two equations were explored for school attractions. These equations used population and households. Normally, a school attraction model will use school enrollment as a primary independent variable, but this data was unavailable and is not expected to be forecasted. An equation using only population (see equation 1) produced an adequate model with a coefficient of determination of 0.87. When population and households were used together, the regression equations coefficient of determination decreased 0.87 to 0.86. The equation showed both independent variables as being significant, with the coefficient on population being positive and the coefficient on household also being positive. This is not a very logical conclusion since using this equation, the estimated school attractions will increase as population increases but will not decrease as the household size decreases.

Like home-based shop/other trips, the non-home-based trip purpose is a potpourri of trips, with the major constraint on the definition being that the trip neither begins nor ends at the traveler's home. It was therefore anticipated that all the land use variables might contribute to explaining the generation of these trips. In this case, the hypothesis was generally correct, with retail employment, non-retail employment, population, and households all having significant positive coefficients. Population and households were tested in separate equations (see equations 3 and 4) and the population variable proved to be superior, with other employment becoming negative. The selected non-home-based trip equation contained, as independent variables, retail employment, non-retail employment, and population. The coefficient of determination for this equation was quite adequate, being 0.97. This non-home-based model will be used to allocate zonal trips, while the production non-home-based model will be used to estimate a regional control total.

The regression analysis for attractions produced a set of logical, statistically sound equations. Although the equations had to be calibrated at the district level, there were only minor indicators that this level of aggregation affected the development of sound attraction models for County-wide analysis.

The final attraction models are shown on Table 21.

APPLICATION STRATEGY

The production and attractions models presented in the preceding sections, when applied to a future year, need not produce balanced trip ends. That is, the work production model may estimate more, or less, productions than attractions generated by the attraction model. This is a normal circumstance for trip generation models since the productions are estimated using absolute land use measures. In order for the distribution model to efficiently use these trip ends to forecast trips, it is necessary to have balanced productions and attractions. This balancing is normally performed by "normalizing" productions to attractions, or vice-versa; the selection of controlling trips depends upon which model is judged to be more appropriate. Normally productions are normalized to attractions for work trips and school trips if enrollment is the independent variable; the reason being that trip rates per employee or students should be fairly stable and not affected by changes in household size or income. For the other trip purposes, attractions are normalized to productions since changes in socio-economic characteristic may affect these trip rates even if land use changes are minimal. The recommended "controls" for the trip generation model are therefore as follows:

Trip Purpose	Model Controlling Region Total
Home-Based Work	Attraction
Home-Based Shopping	Production
Home-Based Other	Production
Home-Based School	Production
Home-Based DVC	Attraction
Non-Home-Based	Production

TABLE 21

FINAL ATTRACTION EQUATIONS

Home-Based Work Attractions

= 1.605 * Total Employment

Home-Based Shop/Other Attractions

= 3.285 * Retail Employment - 0.979 * Other Employment
+ 0.803 * Population

Home-Based Social/Recreational Attractions

= 1.816 * Retail Employment + 0.145 * Service Employment
+ 0.346 * Population

Home-Based School Attractions

= 0.345 * Population

Non-Home-Based Trip Ends

= 5.630 * Retail Employment + 0.017 * Other Employment
+ 0.420 * Population

DEVELOPMENT OF THE TRIP DISTRIBUTION AND MODE CHOICE MODELS FOR CONTRA COSTA COUNTY

GENERAL PLAN REVIEW PROGRAM

Prepared For:

THE COUNTY OF CONTRA COSTA, CALIFORNIA

Prepared by:

Barton-Aschman Associates, Inc.
San Jose, California

November 1987

59140109/GPRP/CCC:87382

1.

TRIP DISTRIBUTION

This chapter presents the results of the calibration of a set of trip distribution models for Contra Costa County. The distribution models calibrated were for five basic trip types: home-based work, home-based shopping/other, home-based social/recreation, home-based school, and non-home-based.

GENERAL MODEL STRUCTURE

There are several approaches commonly used to estimate trips between zones in a region. The gravity model was chosen for the County because of its proven ability to perform satisfactorily.

The gravity model uses a functional relationship of impedance between zones to determine zonal interaction. The gravity model was calibrated for the five purposes described above. This produces trip distributions in enough detail for analysis, while decreasing the error in producing zonal forecasts. In addition, the error in predicting trip productions and attractions is reduced.

The gravity model structure can be applied using the EMME/2 Matrix Calculator. In general, the model postulates that the number of trips from one traffic analysis zone to another is proportional to the attractions[1] at the destination zone and inversely proportional to the travel impedance between the two zones. The general formulation for the gravity model is as follows:

T(I,J)=P(I)*A(J)*F(IMP(I,J))*K(I,J)/SUM OF (A(J)*F(IMP(I,J))*K(I,J))

Where:

T(I,J) is the trips from zone I to zone J

P(I) is the productions[2] for zone I

---

(1) Attractions are trip ends which are not at the traveler's home.

(2) Productions are trip ends which originate at the traveler's home, except in the case of non-home-based trips in which the split between production and attraction is arbitrary.

A(J) is the attractions for zone J

F(IMP(I,J) is the friction factor (F) associated with the impedance (IMP) from zone I to zone J.

and

K(I,J) is the socioeconomic factor for the movement between zone I and zone J.

The usual procedure for developing a trip distribution model for a specific trip purpose is to first estimate the F factor curve which best replicates the observed trip length distribution, and then consider the need for K factors.

The method used to develop a set of F factors consisted of fitting a smooth F factor curve to what is essentially a gamma function. The general formulation for this function is as follows:

$$F(I)=A*I^{B}EXP(C*I)$$

Where:

F(I) is the friction factor for impedance value I

There is considerable evidence that this function may be used to simulate F factors accurately.

CALIBRATION PROCEDURE

The procedure used for estimating the A, B, and C coefficients of the gamma function for a particular trip purpose was as follows:

(1) The gravity model was applied in EMME/2 using observed productions and attractions for a particular trip type. Highway time (peak-hour for work trips, off-peak for non-work trips) was used as the impedance measure.

(2) An EMME/2-produced report summarizing observed and estimated trips by impedance value was edited into a form which could be read by the SYSTAT Package.

(3) The MGLH program within SYSTAT was then used to obtain a weighted least squares fit for the coefficients A, B, and C.

(4) New F factors were calculated by EMME/2 using these coefficients, and the gravity model was reapplied. The observed and estimated trips were again compared, and if the comparison was not adequate, steps 2 through 4 were performed again.

It was found that by using this technique, a good set of F factors could be obtained in between 5 and 6 iterations.

RESULTS OF CALIBRATION

The calibration F factors curves for all trip purposes are shown in Table 1. The F factors are defined by the three coefficients of the gamma function. F factors are non-dimensional values. That is, an F value has no meaning except in its relation to the ot her F values.

Once the factors were calibrated;, the full distribution model was applied. The resulting trip table was then compared with the observed trip table using several tests.

TABLE 1
F-FACTOR CURVES
GAMMA FUNCTION COEFFICIENT VALUES(1)

Trip Purpose	Alpha(2)	Beta	Gamma
Home-Based Work	11.28046	-0.93907	-0.04965
Home-Based Shop/Other	11.46184	-3.49663	-0.01694
Home-Based Social/Recreational	11.10315	-1.79642	-0.09280
Home-Based School	11.22129	-2.30909	-0.12187
Non-Home-Based	11.47886	-2.36714	-0.04838

(1) F-factors calculated using the equation:

$$F(I) = Alpha*I^{(Beta)}* EXP (Gamma*I)$$

Where I = travel time in minutes

(2) Coefficient is a scalar on actual F-factor values

A primary check on the distribution model was to compare the trip length distribution for the estimated trips to the same distribution for the observed trips, using highway time as the impedance measure. For all trips the estimated trip length distributions are very close to the observed. The number of estimated intra-zonal trips also compared favorably with the observed. The estimated versus observed trip length comparisons are presented in Figures 1 through 5.

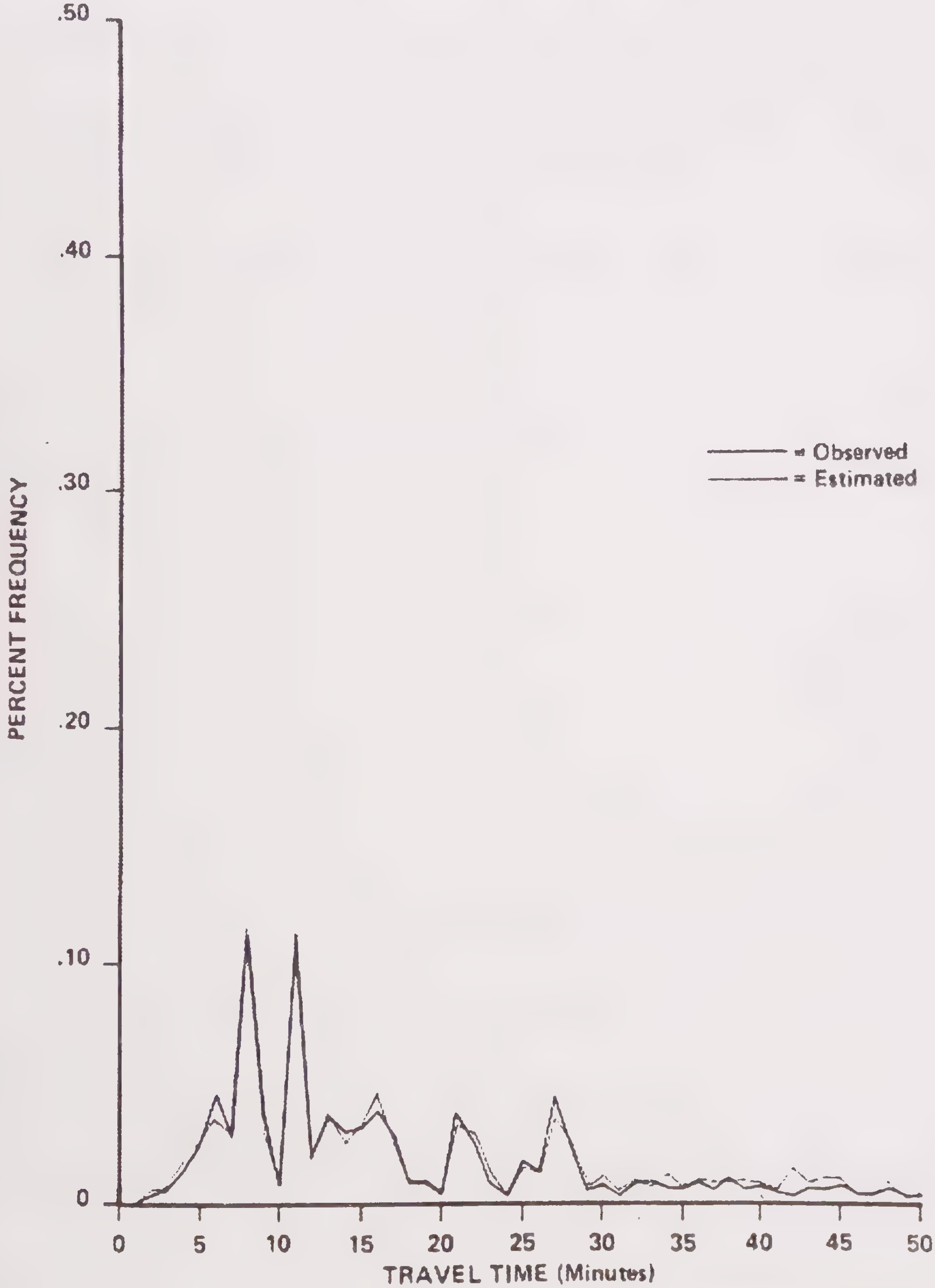

Figure-1

HOME-BASED WORK PERSON TRIPS OBSERVED Vs. ESTIMATED TRIP LENGTH FREQUENCY DISTRIBUTION

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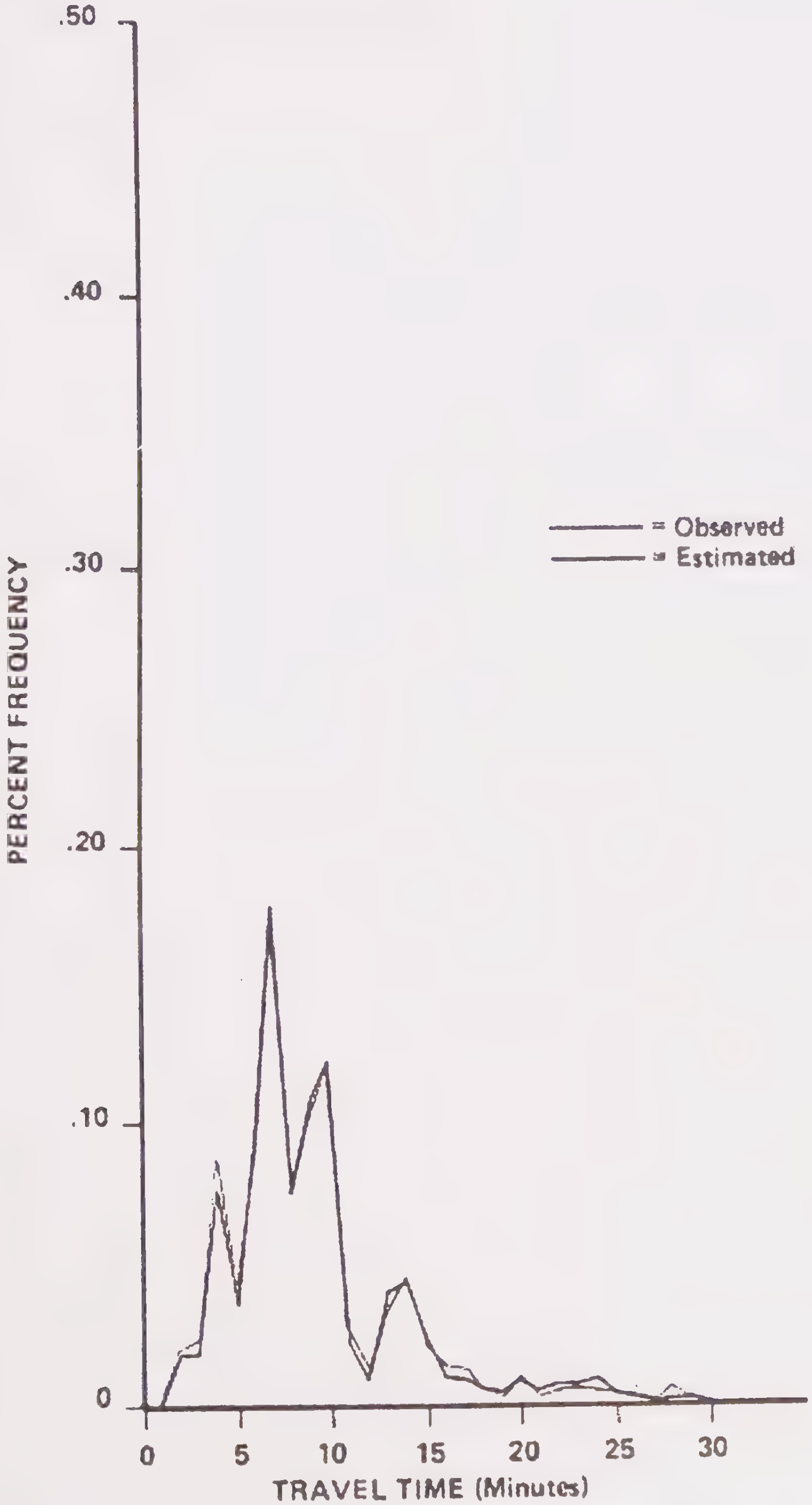

Figure-2

HOME–BASED SHOPPING/OTHER PERSON TRIPS OBSERVED Vs. ESTIMATED TRIP LENGTH FREQUENCY DISTRIBUTION

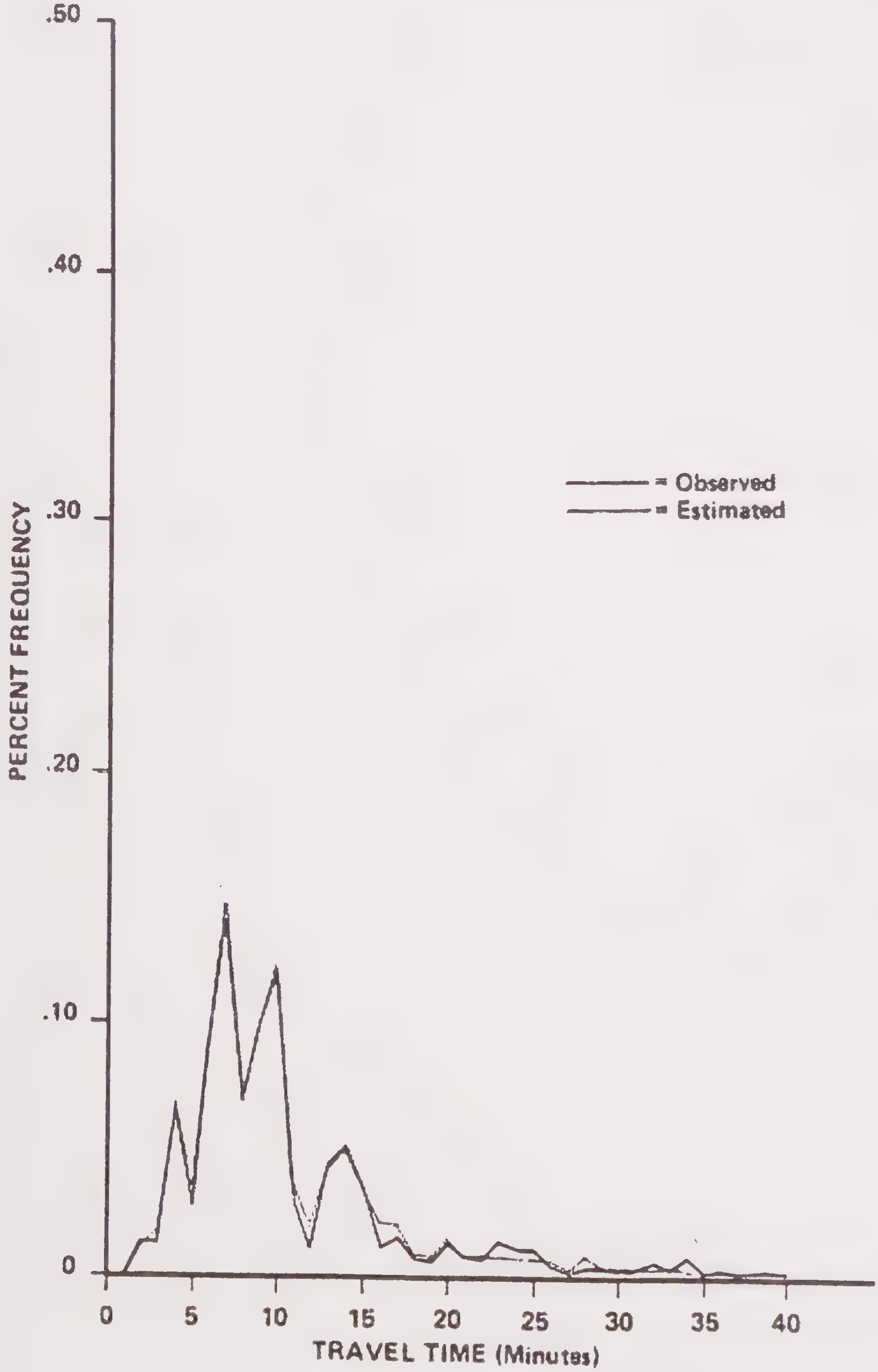

Figure-3

HOME-BASED SOCIAL/RECREATION PERSON TRIPS OBSERVED Vs. ESTIMATED TRIP LENGTH FREQUENCY DISTRIBUTION

Barton-Aschman Associates, Inc.

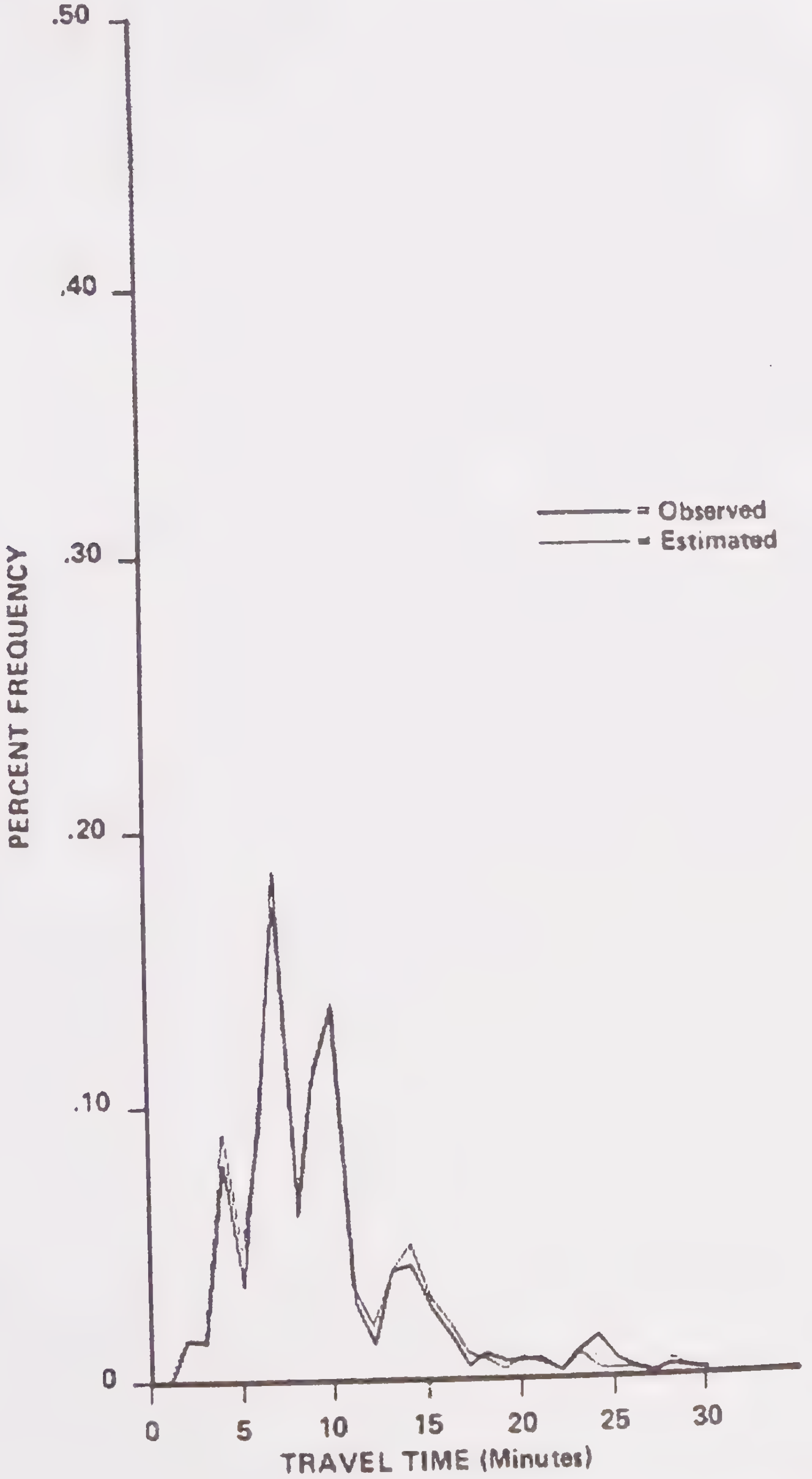

Figure-4

HOME–BASED SCHOOL PERSON TRIPS OBSERVED Vs. ESTIMATED TRIP LENGTH FREQUENCY DISTRIBUTION

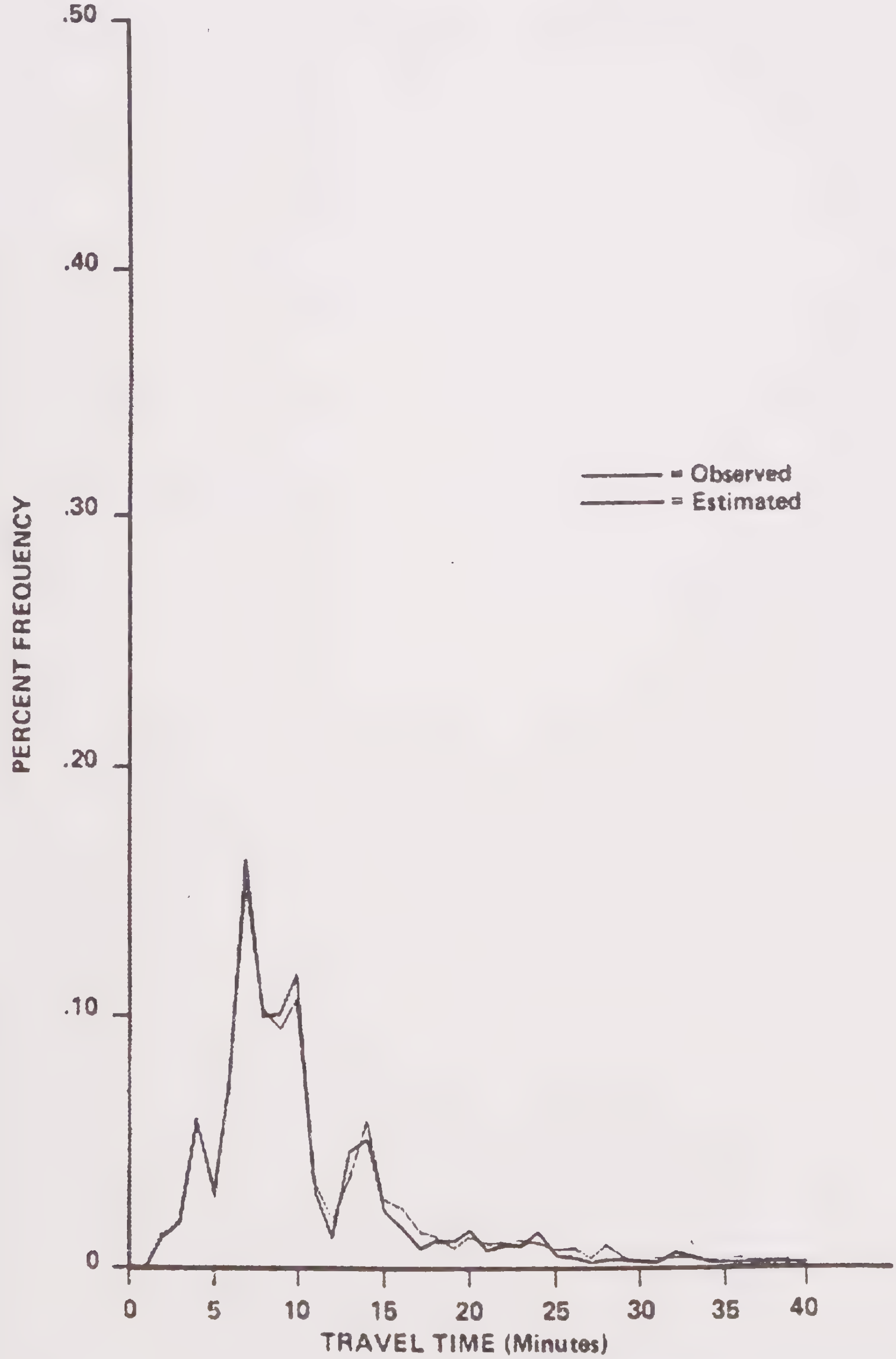

Figure-

NON HOME-BASED WORK
PERSON TRIPS OBSERVED Vs.
ESTIMATED TRIP LENGTH
FREQUENCY DISTRIBUTION

2.

MODE CHOICE MODEL

This section covers the calibration of a set of mode choice models for the County. Mode Choice models are mathematical expressions which can be used to estimate the modal shares of the travel market given the time and cost characteristics of the various competing modes and the socioeconomic characteristics of the urban residents. The mode choice models developed in this project were designed to be an integral link in the travel demand chain, which includes, in addition to the mode choice models, a trip generation model and a trip distribution model. The County models are multinomial logit models which were designed to be policy-oriented trip forecasting models.

MODEL DESCRIPTION AND CALIBRATION METHODOLOGY

General Model Description

The development of the mode choice model utilized a calibration technique which differed considerably from normal estimation procedures. The person trip tables (i.e., trips made by all modes of travel) were synthesized using the County trip generation and distribution models. Calibration, therefore, was not performed using normal estimation programs; but instead was performed using specialized techniques. This section will describe in general terms these techniques.

It was agreed at the beginning of the study that the mode choice models were to use a logit formulation and were to utilize the MTC Regional Models.(3) The logit model formulation relates the probability of choosing a specific mode by using the following equation(s):

$$P_i = \frac{e^{u_i}}{e^{u_k}}$$

Where:

P_i - is the probability of choosing mode i

u_i - is a linear function ofthe descriptors of alterantive i

e^{u_k} - are linear functions of the descriptors of all the alternatives for which a choice is feasible.

(3) "A Disaggregate Work-Trip Mode Choice Model for Aggregate Forecasting," Metropolitan Transportation Commission, August 1986.
"Non-Work Trip Choice Models, Final Disaggregate Version," Metropolitan Transportation Commission, August 1986.

The normal convention for logit models have the functions (the U's) specified as a linear equation. For example:

Mode A = 0.01*Mode A time + 0.02*Mode A cost + Mode A constant

and the U's being the negative value of the linear equation; i.e.,

$$U_A = -\text{Mode A}$$

This convention is followed in this report.

The basic model structure is fairly unique in that it can define multiple modes for the automobile. These modes are one person in an automobile and two persons and three or more persons in an automobile. Only in the home-based work model, however, has this more detailed definition been used.

The primary reason for this model formulation was to allow for the inclusion of specific carpool incentives in the planning process. By the use of multiple highway modes, it is possible to: (1) include specific carpool descriptors, e.g., time and cost; (2) specify and change the description of a carpool; and (3) estimate the effect of the carpool transportation system descriptors on the use of transit.

The overall travel market was stratified by four types of trips, which were:

Home-based work trips - these are trips made between the traveler's home and the place of work.

Home-based shop/other, and school trips - these are trips made between the traveler's home and locations except thework location; i.e., trips made for shopping, personal business, school, etc.

Home-based Social Recreational Trips - these are trips made between the traveler's home and recreation, restaurant locations.

Non-home-based trips - these are trips which do not begin nor end at the traveler's home.

A complete list of independent variables used in the models is listed in Table 2.

GENERAL CALIBRATION METHODOLOGY

Since the standard estimation programs were not used, it was necessary to utilize procedures which would allow the development of calibration constants while still retaining the MTC logit formulation and structure. The procedure used in this effort was primarily to investigate the observed modal shares from the 1981 MTC travel survey.

Logit models are frequently used to estimate a change in mode choice if two items of information are known. These items are: (1) the original percent mode choice, and (2) the absolute change in the "coefficient-variable" product. This attribute is normally used in sketch planning to estimate the change in model usage given a change in a system variable; for example, the change in transit ridership if transit fares are

TABLE 2
INDEPENDENT VARIABLES USED IN MODE CHOICE CALIBRATION

Variable	Description
Transit Variables	
TRN OVTT	Walk time to and from the transit system + waiting time to board the first transit vehicle + waiting time to board the second and subsequent transit vehicles.
TRN RUN	The time spend riding in a transit vehicle + the time spent riding in an automobile to access the transit system.
TRN COST	The cost of using transit (i.e., the total fare) + the mileage-based cost of accessing the system by auto.
AUTO CONN	A "dummy" variable signifying if an automobile was required to access the transit system (No = 0, Yes = 1).
Highway Variables	
HWY RUN (X)	The time spent riding in an automobile, by automobile mode X. (A 5-minute pickup time is added in the Home-Based Work model for 2-person vehicles, while a 7-minute time is added for 3+ person vehilces).
HWY COST (X)	The out-of-pocket cost of using the automobile which includes a cost per mile and appropriate parking cost. Total highway cost is divided by the occupants of the vehicle to obtain the cost for highway mode X.
HWY EXC	The time spent parking and unparking the vehicle.
Socioeconomic Variables	
AHH	The average number of autos owned per houshold.
WHH	The average number of employed residents (workers) per household.
PHH	The average number of persons per household.
INCOME	Average household income ($79)
EMPDEN	Total employment density
RESDEN	Residential Density

increased. For this calibration technique, a model constant is used instead of a system variable (e.g., fare), and a revised constant value is calculated given a desired mode split percentage. This mathematical procedure, which will be described below, is precise when the smallest level of aggregation is used, i.e., an interchange or a trip record, and becomes less precise as the aggregation level increases, although the level of accuracy still remains quite high at aggregation levels used in the calibration process.

Mathematical Derivation

The logit model has the property hat a new probability can be estimated if the absolute change in the utility is known. The basic equation for this attribute is shown below:

$$p^1 = P*K \;/\; (K-1) * P \;+1$$

Where:

K is the exponential of the absolute change in the utility function,
P is the original modal probability, and
p^1 is the new modal probability

A simple transformation of this formula can then be used to estimate an adjustment in a model constant as follows:

$$C^1 = C^o + \mathrm{Ln}\,\frac{pip^o - P^o}{pip^o - P^1}$$

Where:

C^1 = new or revised modal constant
C = original modal constant
Ln = natural logarithm
P^1 = estimated probability
Po = observed or desired probability

In summary, the calibration technique consisted of adjusting the constants of the model in order to "match" the distribution of trips with respect to mode. This adjustment was performed in an interactive manner, making use of the basic mathematical characteristics of the logit formulation.

THE CALIBRATED MODELS

Utilizing the calibration procedures described above, final model constants were developed for each trip purpose. The model coefficients were taken directly from the regional MTC models and were utilized unchanged. The final model equations are presented in Tables 3 through 6.

TABLE 3
MODE SPLIT EQUATIONS FOR HOME-BASED WORK MODEL

Transit	= 0.02543*TRN RUN + 0.05849*TRN OVTT + 0.003871*TRN COST + 1.796*AUTO CONN - 0.7832*(1.10*AHH)
Drive-Alone Auto	= 0.02543*HWY RUN1 + 0.05849*HWY EXC + 0.003871*HWY COST1 + 0.4898*LN(EMPDEN) - 1.507*(1.10*AHH) + 0.4815 *(1.26*WHH) + 0.2676*(1.08*PHH) - 0.00001673* (1.14*INCOME) - 0.9836
2-Person Auto	= 0.02543*HWY RUN2 + 0.05849*HWY EXC + 0.003871*HWY COST2 + 0.3838*LN(EMPDEN) - 0.9668*(1.10*AHH) + 0.2090 *(1.26*WHH) - 0.00001458*(1.14*INCOME) + 1.0222
3+ Person Auto	= 0.02543*HWY RUN3 + 0.05849*HWY EXC + 0.003871*HWY COST3 + 0.3838*LN(EMPDEN) - 0.9668*(1.10*AHH) + 0.2090 *(1.26*WHH) -0.00001458*(1.14*INCOME) + 2.0619

TABLE 4

MODE SPLIT EQUATIONS FOR HOME-BASED SHOP/OTHER/SCHOOL MODEL

Transit	= 0.0176*(TRN RUN + TRN OVTT) + 0.01005*TRN COST
Auto Person	= 0.0176*HWY RUN + 0.01005*HWY COST - 0.701*AHH + 0.2755*PHH + 0.6094*LN(RESDEN) + 0.6052*LN(EMPDEN) - 0.3699
Auto Occupancy Value	= 1.241

TABLE 5
MODE SPLIT EQUATIONS FOR HOME-BASED SOCIAL-RECREATIONAL MODEL

Transit	= 0.004352*(TRN RUN + TRN OVTT) + 0.00333*TRN COST
Auto Person	= 0.004352*HWY RUN + 0.00333*HWY COST - 0.5331*AHH + 0.2382*PHH + 0.05592*RESDEN + 0.007032*EMPDEN - 2.917
Auto Occupancy Value	= 1.730

TABLE 6
MODE SPLIT EQUATIONS FOR NON-HOME-BASED MODEL

Transit	= 0.01024*(TRN RUN + TRN OVTT) + 0.004479*TRN COST
Auto Person	= 0.01024*HWYRUN + 0.004479*HWY COST + 0.002113*RESDEN(I) + 0.002559*RESDEN(J) + 0.003299*EMPDEN(I) + 0.001183*EMPDEN(J) - 2-4907
Auto Occupancy Value	= 1.254

APPENDIX F

EVALUATION OF WATER, SEWER, AND STORM DRAINAGE INFRASTRUCTURE

Contra
Costa
County

Evaluation of Water, Sewer, and Storm Drainage Infrastructure Requirements- Composite and Spread Alternatives

Revised
January 1989

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CHAPTER 1

INTRODUCTION AND SUMMARY

This report summarizes the evaluation of the water, sewer, and storm drainage infrastructure needs in Contra Costa County (County). The needs were determined with respect to two alternative growth scenarios: (1) buildout of the existing county, city, and special area general plans (Composite Alternative), and (2) Composite Alternative growth plus buildout of additional growth areas outside of existing general plans (Spread Alternative). The additional areas of growth that are included as part of the Spread alternative are selected potential areas of growth and do not constitute all potential future areas of growth. It should be noted that neither of these scenarios are calibrated to projected population distribution to the year 2005, as contained in the Association of Bay Area Governments (ABAG) projections.

Scope of the Investigation

The purpose of this study was to evaluate whether and how future growth according to these two scenarios could be accommodated and at what cost. Water, sewer, and storm drainage were studied independently. Only rough cost estimates were required for planning purposes. This study was not intended to dictate exactly how the infrastructure facilities would be built or to lay out a detailed master plan showing future pipelines or facilities required.

Water and Sewer Service

A total of 25 agencies currently provide either water, sewer, or both types of service. These agencies have been expanding their service areas and building new facilities as they are needed. In general each agency has been guided by a master plan showing the location and capacity of future facilities. Capital improvement programs, extending 5 or more years in the future, list needed facilities. These plans have been prepared by service agency staff or private consultants and are based on these authors' own estimate of future growth.

Brown and Caldwell collected available master plans and capital improvement programs. Some are very detailed, listing every pipe down to 12-inch size; others are general in nature. None of the population projections exactly matched the County's two alternative growth scenarios.

The approach taken in the evaluation was to first allocate future population for the two growth scenarios to the likely service provider. The costs for a particular provider, obtained from a master plan or other references, were adjusted for application to the Composite or Spread alternative population projections. In this way the future cost estimates are directly applicable to the population forecasts developed for this study.

The water and sewer supporting material used in this evaluation is extensive in most areas, unless no master plan exists. The support material is in the form of reports, tables listing capital improvement programs, and some maps of future facilities. It is available from Brown and Caldwell upon request. This report summarizes the approach used to estimate costs and describes how service would be provided. It is general because extensive backup is available.

Principal Findings, Water. The findings relate to how water service can be provided at the same high levels of service county residents have come to expect.

1. Growth projections for the Composite and Spread Alternatives show substantially more growth than East Bay Municipal Utility District and the City of Brentwood are planning in their respective service area and substantially less growth than currently planned by Contra Costa Water District (see Table 2-1).

2. It appears that East Bay Municipal Utility District will have difficulty providing water to the Dougherty Valley area without a new water supply or additional storage in the East Bay Area. They are not about to run out of water but providing water service to this area would probably cause their total average water use to exceed self-imposed limits that are based on the level of rationing imposed during water supply shortages. The cost to serve this area may be very high depending upon the timing of the growth.

3. The City of Brentwood needs a long-term water supply; otherwise, the City will not be able to accommodate growth projected for the area.

4. A long-term supply of water has not been identified for the projected populations in other east county areas experiencing substantial growth including Bethel Island and the Veale Tract. The Contra Costa Water District is interested in providing water service in the east county area; this could solve the east county water supply issues.

Principal Findings, Sewer Service. Sewer service to west and central Contra Costa County has been planned adequately to meet

projected demand resulting from future development. Several issues have been identified that may influence sewer service to east county areas.

1. Central Contra Costa Sanitary District is the major sewer service provider and is building adequate capacity to accommodate either the Composite or Spread Alternatives, as they affect their service area. This includes the Dougherty Valley area.

2. Growth projected for the Oakley-Bethel Island area is far in excess of current wastewater treatment/disposal capacity.

3. The present method of treated wastewater disposal in the Oakley, Bethel Island, and Brentwood areas, i.e., land disposal probably will be impractical in the future due to the large amount of land that would be required for land disposal of wastewater generated from the planned growth. A wastewater discharge into the San Joaquin River would be problematical due to the proximity of water supply intakes, including the state water project. In this evaluation, we have assumed that disposal will be by bay outfall, in the vicinity of the Delta Diablo Sanitation District outfall near Pittsburg. Other options such as tertiary treatment and reuse for agriculture should be considered.

Storm Drainage

The implementation of drainage facilities in the County falls under the jurisdiction of the various municipalities, the County for the unincorporated areas, and the County Flood Control District which has adopted regional plans that serve both cities and County. All three groups use the hydrology design criteria developed and maintained by the Flood Control District. Further, these entities use basically the same design criteria in sizing and evaluating drainage systems. The basic unit for storm drainage planning is a watershed. Watershed boundaries, which do not coincide with political boundaries, were used as the unit of planning in this evaluation.

Unlike domestic water and sanitary systems, the drainage of stormwater is a natural occurrence, i.e., water flows downhill and, as of yet, it is not treated or processed. Consequently, much of the drainage system serving the County consists of natural drainage swales, ditches, and watercourses. During the urbanization process, most of the swales and ditches are replaced with underground storm drains or concrete-lined ditches by developers. To a lessor extent, natural watercourses (creeks) are also improved during the development process. However, the latter occurs only when the natural watercourses are determined to be inadequate or interfere

with the proposed development plan. Some regional plans have been developed by some of the cities, the County, and the Flood Control District to help facilitate the implementation of new drainage systems by the development community and federal flood control programs.

Future growth, based on the Composite and Spread Alternative growth scenarios, was allocated to the various watersheds. Cost estimates were prepared for each watershed based on the amount of new impervious surface expected to be created and a standard per square foot cost of $0.35. The per square foot cost is based upon experience of the Contra Costa County Flood Control and Water Conservation District. A list of the watersheds and associated costs was prepared.

Principal Findings, Storm Drainage. Flood Insurance Rate Maps are now available showing the 100-year floodplain throughout the County. New development needs to be carefully planned so that it does not aggravate these potential and existing problems.

1. There are five general types of projects that will need to be built in the future:

   a. Local collector drainage systems needed to accommodate future development.

   b. Regional drainage facilities required by the various development codes and needed to mitigate the resultant increase in peak runoff from urbanization.

   c. Local drainage facilities needed to solve existing problems in the older urbanized areas.

   d. Regional drainage facilities needed to solve the existing inadequate capacity and erosiveness of the natural watercourses serving the existing urbanized areas.

   e. Levee rehabilitation needed to improve the structural integrity of existing levees.

2. Present procedures for requiring all new development to pay their fair share of needed drainage infrastructure are cumbersome and inconsistently applied. Many, but not all, of the major developments are required to mitigate the increase in stormwater runoff from their developments. However, many of the small developments contribute nothing to the regional mitigation solution. Also, many of the smaller developments located in existing urbanized areas are too small to bear the full cost of needed drainage. Frequently, these developments are allowed to proceed

without contributing to the long-range solutions. Another problem is inconsistencies in the amounts of drainage improvement requirements of developments by the various cities and the County.

Existing regulations for the formation of drainage entities and the adoption of fees are time-consuming. The process is further complicated by a lengthy period of study and evaluation of alternatives to find a solution that is functional, economically feasible, and environmentally and socially acceptable.

Following adoption of a plan, drainage fees can be assessed against new development within the drainage area. Because drainage fees can only be assessed on new developments occurring within adopted drainage areas, developments built within areas not yet established as adopted drainage areas do not have to pay any drainage fees. However, they still must comply with drainage requirements imposed as a condition of approval of the development.

3. There is a large number of unfunded projects needed to correct existing problems. The total cost of these projects is on the order of $500 to $800 million. Included in this estimated cost is $53 million for levee rehabilitation as discussed in item number 4 below. Many of these problems are in the central and west county areas. Because many of the affected areas are already developed, little assistance from future development can be expected. The federal and state governments have provided some funding for projects such as these, but there is still a large shortfall.

4. The levees in the Bethel Island, the Hotchkiss Tract, and the Veale Tract areas are considered to be inadequate and require rehabilitation. The State Department of Water Resources has estimated costs of $39, $8, and $5 million, respectively, that would be required for flood protection for existing land uses. Major new subdivisions may warrant even greater investments for adequate protection. The other issues that need to be addressed in the rehabilitation of levees are the continued settlement of the levees for these Delta islands due to subsurface conditions and the expected rise in Delta water surface due to the anticipated rise in ocean levels.

Summary of Cost Estimates

Shown in Table 1-1 are the rough costs for meeting infrastructure needs through the buildout of the two growth scenarios. The costs for the Spread Alternative are shown in incremental terms

Table 1-1 Summary of Cost Estimates

Element	Alternative scenario cost estimates, dollars		
	Composite	Incremental cost for Spread	Total Spread
Water	220,615,000	156,294,000	376,909,000
Sewer	205,029,000	66,579,000	271,608,000
Storm drainage[a]	228,632,000	104,344,000	332,973,000
Total	654,276,000	327,217,000	981,493,000

[a]The storm drainage costs do not include regional flood control improvement cost estimates.

over and above costs defined for the Composite Alternative as well as total costs. These costs exclude local water, sewer, and storm drainage facilities installed by developers to serve their particular project. The needed regional flood control costs to handle existing problems are also excluded. All costs are normalized to 1987 dollars.

CHAPTER 2

WATER SERVICE

Water service in Contra Costa County (County) is provided by nine separate cities or special districts. These agencies were contacted to discuss expansion plans with respect to projected growth within and adjacent to existing service boundaries. Planning by the agencies is facilitated by preparation of a water master plan. Water master plans, typically updated at 5- to 10-year intervals, provide service area growth projections and present a capital improvement program (CIP) that is developed to accommodate that projected growth. In general, the CIPs identify facilities to be built within the next 5 to 20 years. This chapter compares agency growth projections with those developed by the County and provides rough costs to provide water service needed to accommodate the County's projections.

Population projections for the two future growth scenarios are shown in Table 2-1. The water service agency 1985 population forecasts are estimated using several estimation methods. As an example, some agencies derive these estimates by multiplying a known number of water service connections by an average persons per household estimate. The County analysis derived population projections from actual census tract populations disaggregated to traffic zones. Therefore, some variation was anticipated between the County analyses by traffic zones and the 1985 service agency population projections. In Table 2-1, agency projections are also shown for an additional year in the future. These projections were obtained from discussions with agency representatives or from the most recent agency water master plan or urban water management plan. In general, the agencies are now building to accommodate growth based on these projections. In some cases, there are large differences between the agency and the County traffic zone population projections. For example, East Bay Municipal Utility District is planning for fewer people than the County Spread Alternative whereas Contra Costa Water District anticipates substantially larger growth increments. These differences and our approach to dealing with these differences are discussed for the particular agency involved.

ACCOMMODATING FUTURE GROWTH

This section presents a brief overview of water agency plans to accommodate the growth projected by the County, as assigned to water service areas by Brown and Caldwell. Appendix A provides a

Table 2-1 Existing and Projected Water Service Population Estimates in Contra Costa County

Water service entity	Traffic zone analysis population estimates		Service agency population estimates		Water demand (design capacity)
			Population	Year	
East Bay Municipal Utility District	1985	374,894	363,400	1985	220 mgd
	Composite	449,570	435,000	2010	(325 mgd)
	Spread	504,724	-		
Contra Costa Water District	1985	176,982	201,000	1987	32.6 mgd
	Composite	190,122	276,000	2000	(100 mgd)
	Spread	190,947	303,000[a]	Ultimate	
Antioch	1985	49,708	47,273	1985	
	Composite	86,396	91,100	2005	(16 mgd)
	Spread	100,571			
Martinez	1985	27,481	26,611	1985	
	Composite	33,998	32568	2005	(10.2 mgd)
	Spread	33,998			
Pittsburg/West Pittsburg (Southern California Water Company)	1985	52,130	42,114	1985	
	Composite	68,585	62,745[b]	2010	(Pittsburg: 16 mgd)
	Spread	74,837			(West Pittsburg: 4.1 mgd)
Oakley Water District	1985	9,081	7,500	1985	4 mgd (1987)
	Composite	29,843	25,000	2000	(6.2 mgd)
	Spread	29,843			
Brentwood	1985	7,804	5,400	1986	0.86 mgd
	Composite	44,768	21,000	2005	(3 mgd)
	Spread	48,684			
Byron	1985	704	300	1987	0.045 mgd
	Composite	632			
	Spread	632			
Discovery Bay	1985	2,942	2,900	1987	NI
	Composite	8,148			
	Spread	8,148			

[a]Includes West Pittsburg.
[b]Excludes West Pittsburg.

Notes:
1. For the purposes of this evaluation, Pittsburg and West Pittsburg were included as part of a single service area. Southern California Water Company is currently the water service provider for the West Pittsburg area. As footnoted in the table, the Contra Costa Water District has included the West Pittsburg population in their ultimate population projection.
2. "Bethel Island area" refers to the region defined by the Spread alternative development in the vicinity of Bethel Island.
3. "Veale Tract area" refers to the region defined by the Spread alternative development in the vicinity of the Veale Tract.
4. "Unallocated population" refers to that portion of the total estimated population for each alternative growth scenario that was located outside of the various agency service boundaries.
5. The water demand column identifies the demand for water by the service population identified in the table. The existing water treatment capacity is shown in parentheses.
6. "NI" indicates not identified.

Table 2-1 Existing and Projected Water Service Population Estimates in Contra Costa County (continued)

Water service entity	Traffic zone analysis population estimates		Service agency population estimates		Water demand (design capacity)
			Population	Year	
Bethel Island area	1985	2,714	NI	NI	NI
	Composite	8,636			
	Spread	18,705			
Veale Tract area	1985	631	NI	NI	NI
	Composite	607			
	Spread	14,738			
Unallocated population	1985	4,018	NI	NI	NI
	Composite	2,719			
	Spread	2,493			

[a]Includes West Pittsburg.
[b]Excludes West Pittsburg.

Notes:
1. For the purposes of this evaluation, Pittsburg and West Pittsburg were included as part of a single service area. Southern California Water Company is currently the water service provider for the West Pittsburg area. As footnoted in the table, the Contra Costa Water District has included the West Pittsburg population in their ultimate population projection.
2. "Bethel Island area" refers to the region defined by the Spread alternative development in the vicinity of Bethel Island.
3. "Veale Tract area" refers to the region defined by the Spread alternative development in the vicinity of the Veale Tract.
4. "Unallocated population" refers to that portion of the total estimated population for each alternative growth scenario that was located outside of the various agency service boundaries.
5. The water demand column identifies the demand for water by the service population identified in the table. The existing water treatment capacity is shown in parentheses.
6. "NI" indicates not identified.

listing of written references and individual contacts utilized in the preparation of this document. Rough cost estimates were prepared by modifying the agency provided cost estimates to fit the growth projected by the County traffic zone analysis. These costs are shown in Table 2-2 and discussed in the following paragraphs. Costs include treatment, transmission, and storage but exclude local water distribution costs that would be installed by developers. These local costs will be included in the financial analysis prepared by Economic and Planning Systems, the economic/ fiscal consultants on the consultant team. The cost for the Composite Alternative totals $220,615,000. The incremental cost for the Spread Alternative is estimated to be $156,294,000. The total estimated cost for water service capacity expansion to meet projected future development needs of Composite and Spread Alternative scenarios combined is $376,909,000.

East Bay Municipal Utility District

East Bay Municipal Utility District (EBMUD) has been expanding their water system to accommodate growth in Contra Costa County, focusing recently on the San Ramon Valley. The most recent document that discusses EBMUD population projections is an urban water management plan prepared in 1985. They are finalizing a water supply management program that discusses possible ways to improve the water delivery system to ensure continued reliable water supply for the East Bay. In 1987, EBMUD updated a list of facilities and costs to accommodate growth within their present service area. The EBMUD estimated total cost for all of their required projects is $224,173,000, of which $102,000,000 is for growth in the San Ramon Valley. Some of these projects have been built, and others are either currently under construction, or are planned for construction in the future.

A key question to be asked is whether EBMUD will be able to supply the water required for projected growth. This is a complex question, the answer for which is influenced by many factors. EBMUD has water rights to 325 million gallons per day (mgd) from the Mokelumne River, which is available during normal weather conditions. EBMUD policy is that their acceptable maximum level of average demand is 240 mgd. This is predicated on the fact that the hardship endured by their customers during any repeat of the 1977-78 drought should be no worse than it was then. Were EBMUD to allow the average water use to rise above this level, by accommodating more growth for example, then the hardship would increase. For instance, instead of asking for a 25 percent cut-back in water use by their customers they might have to ask for 35 percent. This may cause increased economic losses. Current average water demand in 1985 was about 220 mgd. EBMUD projects water demand to rise to about 240 mgd around the year 2000 plus or minus 5 years depending upon the success of their water conservation program. During this 15-year period, EBMUD expects to serve

Table 2-2 Cost Estimates for Water Service in Contra Costa County for the Composite and Spread Alternatives

Water service entity		Cost for Composite alternative, dollars	Incremental cost for Spread alternative, dollars
East Bay Municipal Utility District	Transmission/storage Treatment	76,095,000 16,653,000	70,200,000 37,000,000
Contra Costa Water District	Transmission/storage Treatment	5,830,000 0	379,000 0
Martinez	Transmission/storage Treatment	7,069,000 1,715,000	0 0
Pittsburg/West Pittsburg (Southern California Water Company)	Transmission/storage Treatment	10,600,000 4,100,000	7,100,000 400,000
Antioch	Transmission/storage Treatment	23,517,000 7,400,000	9,085,000 2,800,000
Oakley Water District	Transmission/storage Treatment	4,291,000 18,557,000	0 0
Brentwood	Transmission/storage Treatment	28,031,000 5,106,000	7,000,000 500,000
Byron	Transmission/storage Treatment	0 0	0 0
Discovery Bay	Transmission/storage Treatment	1,378,000 285,000	0 0
Bethel Island area	Transmission/storage Treatment	8,399,000 1,589,000	7,451,000 1,410,000
Veale Tract area	Transmission/storage Treatment	0 0	10,906,000 2,063,000
Totals		220,615,000	156,294,000

Notes:
1. Local on-site distribution costs are not included in these cost estimates.
2. "Bethel Island area" refers to the region defined by the Spread alternative development in the vicinity of Bethel Island.
3. "Veale Tract area" refers to the region defined by the Spread development in the vicinity of the Veale Tract.

approximately an additional 55,000 people in their service area. This is 31,000 people less than the amount of growth projected for the Composite Alternative and about 86,000 people short of the Spread Alternative. EBMUD is pursuing a sufficiently large supplemental source of water (the American River) and is investigating demand reduction and conservation options. Based on the current water rights allocation, EBMUD does have the volume of water needed to support projected growth. However, construction of transmission and storage facilities would be needed to make the EBMUD water supply available to the projected population.

Water for the San Ramon Valley comes from the EBMUD Walnut Creek filter plant, located near the Mokelumne Aqueducts in Walnut Creek. There is no easy way to expand the plant beyond expansions that are currently planned. A new filter plant in the San Ramon Valley may be considered as a new southern branch of the Mokelumne Aqueducts.

Assuming that EBMUD can develop their full water entitlement and construct the needed storage, they will be able to provide treatment and distribution facilities to accommodate growth forecast by the Composite Alternative. The Composite Alternative growth projections are close to the EBMUD forecasts. However, providing facilities for the Spread Alternative will be problematic and expensive. First, the Spread Alternative (Dougherty Valley) is made up of some areas outside of the EBMUD district boundaries, and an annexation procedure would be required to expand the present boundaries and planning area. Additionally, the EBMUD water rights permit may require modification. An important consideration is that if the Spread Alternative areas are ultimately annexed to the District <u>after</u> their currently planned construction projects are completed, then additional construction of a comparable scale will be needed. If the Spread development is to be served, the additional 50,000 people at one end of their service area would require a 60-inch pipe estimated to cost up to $1,000 per foot to install in congested areas such as Walnut Creek. Furthermore, the north-south rights-of-way are becoming full with other pipes. From an engineering standpoint, it is more logical to decide whether and how to serve the Spread Alternative areas <u>now</u> and upsize planned transmission mains <u>before</u> they are built.

In order to provide an order-of-magnitude cost estimate for supplying water to the projected Spread Alternative population in eastern San Ramon, it was assumed that EBMUD would be able to expand their service area. The estimated cost is based upon a new 60-inch line connecting to the Mokelumne Aqueduct in the east county area around Bixler. Construction in an unpopulated or sparsely populated area would be less disruptive and less expensive than construction in a densely populated area such as Walnut Creek. The transmission pipeline for this alternative would be 25 miles long. Additional facilities would include a 50-mgd

pumping station and filter plant. The cost for this would be around $100,000,000. It is anticipated that a project such as this would be controversial since it may invite requests for additional district annexations along the pipeline route in the east county area. There is a slim chance that water could be supplied from the Dublin San Ramon Services District (DSRSD) as a feasible alternative means of water supply. In all likelihood, less expensive ways would be found either by upsizing EBMUD planned facilities or obtaining water from DSRSD, but because neither of these alternatives is assured they were not pursued further.

Contra Costa Water District

Contra Costa Water District (CCWD) is the second largest supplier of treated water in the County. CCWD serves treated water to approximately 200,000 people in the Concord, Walnut Creek, Pleasant Hill, and Clayton areas and wholesales raw water to the Cities of Antioch, Martinez, Pittsburg, and Oakley. CCWD water is withdrawn from the Delta at Rock Slough. They have water rights to about twice their current use, contracted from the U.S. Bureau of Reclamation.

The current focus of CCWD is to improve the quality of their water supply by lowering the total dissolved solids content. This goal can be facilitated by construction of a proposed large reservoir in the southeastern portion of the County. This proposed reservoir, called Los Vaqueros, would store better quality Delta water that would be available during the winter months for blending during the peak demand/lower water quality supply months occurring during summer and fall. Other agencies, such as EBMUD and Alameda County Zone 7, have been asked to participate in the project.

In comparing the County traffic zone population projections within the CCWD service area to CCWD's own projections, large differences are noted. There is even a significant discrepancy with the current service population estimates. The population growth estimates of CCWD provide for taking over water service in West Pittsburg from Southern California Water Company. About 15,000 people live there now. Nevertheless, based on preliminary CCWD population figures, CCWD is planning and anticipates building for a population that is 50 percent higher than the County's estimate. The explanation provided by CCWD is that their estimates anticipate substantial redevelopment and densification within their existing service area. Additionally, CCWD is interested in serving treated water in the Oakley-Brentwood area but no agreements have been made yet and this is not included in their population forecasts.

The costs presented in Table 3-2 are considerably less than anticipated by CCWD. The costs are based on CCWD cost estimates

from a recent master plan but were scaled down to accommodate the more modest growth indicated by the County projections by traffic zones.

Antioch

The City of Antioch is growing at a rapid rate and is expanding their water treatment and distribution capabilities to keep pace with the growth. A major water treatment plant expansion is under way and additional 8-mgd modules, capable of serving 20,000 people each, are planned. The City and County population projections are fairly close, so costs from recent City studies were usable with only minor modifications.

Martinez

The City of Martinez is one of the slower growing areas of the County. Rehabilitation and a modest expansion of their water treatment plant is planned. Additions to their water distribution system will be built to handle growth. Costs were obtained from a recent water master plan prepared by Brown and Caldwell.

Pittsburg/West Pittsburg

Pittsburg is growing fairly rapidly and has just completed studies of their water treatment plant and water distribution system. Their water treatment plant will be expanded soon, in modular fashion. Distribution system improvements, including provision for the southwest hills Spread Alternative development area, have been detailed in a recent master plan.

Oakley Water District

The Oakley area is slated for rapid growth and the Oakley Water District (OWD) is planning for expansion. The OWD has had a recent water master plan prepared which anticipates growth similar to the County traffic zone projections. The cost estimates that are presented in the water master plan are for construction of facilities for increased capacity to 16 mgd. Based on the existing per capita water demand in the OWD, the 16-mgd projected design capacity is sufficient to accommodate the Composite and Spread Alternatives. Prior to expansion of OWD facilities, arrangements may be made to obtain 1-mgd treated water from the City of Antioch.

Brentwood

The City of Brentwood is currently purchasing surplus water from EBMUD. This was granted on a temporary basis because of high nitrate concentrations identified in City of Brentwood well water. Recent reports prepared by the City indicate the need for a permanent, long-term water supply, particularly in view of the substantial growth planned for the area.

The population projections provided in the water supply study prepared for the City were significantly below the County traffic zone analysis projections (21,000 vs. 44,768). Additionally, the cost estimates associated with the report were based on treatment requirements using a water source such as EBMUD which requires minimal treatment. The future source of City of Brentwood water is currently undecided. Therefore, the cost estimates prepared for future water treatment and distribution facilities were based on studies done by Brown and Caldwell evaluating facility expansion costs for other similarly sized communities.

Byron and Discovery Bay

The Byron and Discovery Bay communities rely on a well water supply. The Byron community consists of private wells with no water treatment. On the basis of the County's population analysis by traffic zones, no growth is projected for the Byron community. Therefore, there are no projected capacity expansion costs. The decrease in population for Byron from 1985 to the Composite/Spread Alternatives is a result of a generalized reduction in average household size in the County during the period from 1985 to 2005.

For Discovery Bay, water service responsibilities have been contracted out to Delta Diablo Sanitation District. Four community water supply wells have been constructed. The water service cost estimate for Discovery Bay is based on design and construction of a fifth water supply well and associated facilities and installation of distribution facilities required as a result of population growth. All Discovery Bay well water undergoes chlorination treatment. Currently, there are no limitations regarding water supply related to pumping or chlorination capacity.

Bethel Island and Veale Tract Areas

The Bethel Island and Veale Tract areas are anticipated to experience a significant amount of growth; 15,991 and 14,107 population increases, respectively, between the 1985 and the Spread Alternative populations. Currently, the Bethel Island and Veale Tract communities rely on well water for a water supply. A well water supply is not expected to be adequate to accommodate the population projected for these areas.

CCWD has expressed interest in providing water service to east County areas by means of a regional water treatment plant. This is a possible source of water for the Bethel Island and Veale Tract areas. Before extensive development could occur, a water supply source would have to be identified. The cost estimates prepared for future water treatment and distribution facilities were based on studies done by Brown and Caldwell evaluating facility expansion costs for other similarly sized communities.

CHAPTER 3

SEWER SERVICE

Sewer service in Contra Costa County (County) is provided by 13 municipalities or special districts. Consistent with the approach utilized for water service, each of the service agencies were contacted to discuss expansion plans with respect to projected growth within and adjacent to existing service boundaries. If available, sewer master plans and capital improvements plans were consulted as additional sources of information. Appendix B provides a listing of references and individual agency contacts utilized in the preparation of this document. This chapter presents a comparison between County traffic zone growth projections and sewer service agency growth projections and provides cost estimates for capacity expansions required to meet demand resulting from new development.

COMPARISON OF GROWTH PROJECTIONS

Population projections for the Composite and Spread Alternative growth scenarios are shown in Table 3-1. The sewer service agency 1985 population estimates were made in a manner similar to water service estimates. In the table, agency projections are generally provided for an additional year in the future.

Areas of future development projected outside of existing service boundaries could generally be accommodated by expansion of a particular service agency. However, there were instances in which a given development could conceivably be served by one of several agencies. Because the objective of this document is to estimate the cost of providing service to a future development rather than making a political decision as to who would serve it, cost information available from more than one sewer service agency source was evaluated in developing these costs. As an example, the cost estimate for service to the Dougherty Valley area includes information derived from both the Central Contra Costa Sanitary District (major collection and transport pipelines and treatment) and Dublin San Ramon Services District (trunk pipeline collection network).

Table 3-1 Existing and Projected Sewer Service Population Estimates in Contra Costa County

Sewer service entity	Traffic zone analysis population estimates		Service agency projection estimates		Existing flows (ADWF) (design capacity)
			Population	Year	
Central Contra Costa Sanitary District	1985 Composite Spread	352,354 408,371 467,158	338,000 442,000 525,000	1985 1995 ultimate	35 mgd (45 mgd)
Delta Diablo Sanitation District	1985 Composite Spread	100,769 157,823 175,272	101,520 160,967	1985 2005	8.04 mgd (13.5 mgd)
Stege Sanitary District	1985 Composite Spread	36,651 32,656 32,656	32,800		3.7 mgd (14 mgd)
West Contra Costa Sanitary District	1985 Composite Spread	67,747 77,161 77,161	75,000	1987	7.5 mgd (12.5 mgd)
Mountain View Sanitary District	1985 Composite Spread	15,834 19,881 19,881	15,000 29,000	1987 ultimate	1.6 mgd (1.6 mgd)
Dublin-San Ramon Sanitary District	1985 Composite Spread	12,453 17,927 17,927	NI		(11.5 mgd)
Rodeo Sanitary District	1985 Composite Spread	8,189 7,387 7,387	8,250	1987	0.825 mgd (1.14 mgd)
Crockett-Valona Sanitary District	1985 Composite Spread	3,019 3,065 3,065	2,890	1987	0.3 mgd (2.69 mgd)[a]
Oakley-Bethel Island Wastewater Management	1985 Composite Spread	9,605 38,228 48,297	12,656	1987	1.0 mgd (1.5 mgd)
Byron Sanitary District	1985 Composite Spread	704 632 632	300	1987	0.03 mgd
City of Richmond	1985 Composite Spread	52,857 53,824 53,824	53,000 57,000	1987 2005	6.5 mgd (16 mgd)

[a]Of the total treatment plant capacity, the allocation for the Crockett-Valona Sanitary District is 0.3 mgd. See text for further explanation.

Notes: 1. The existing flows column identifies the flows generated by the Service Agency population identified in the table. The existing sewage treatment capacity is shown in parentheses.
2. "NI" indicates not identified.
3. "ADWF" indicates average dry-weather flow.
3. "mgd" indicates million gallons per day.
4. "gpd" indicates gallons per day.

Table 3-1 Existing and Projected Sewer Service Population Estimates in Contra Costa County (continued)

Sewer service entity	Traffic zone analysis population estimates		Service agency projection estimates		Existing flows (ADWF) (design capacity)
			Population	Year	
City of Hercules City of Pinole	1985 Composite Spread	23,594 41,743 41,743	25,000	1987	2.4 mgd (4.3 mgd)
Discovery Bay	1985 Composite Spread	2,942 8,148 8,148	1,550	1987	0.45 mgd (1.2 mgd)
Port Costa	1985 Composite Spread	193 208 208	250	1987	6,500 gpd (33,000 gpd)
Brentwood	1985 Composite Spread	7,805 44,768 48,684	7,500 21,000	1987 2005	0.55 mgd (0.6 mgd)
Veale Tract area	1985 Composite Spread	631 607 14,738	NI	NI	NI
Unallocated population	1985 Composite Spread	13,742 11,595 11,539	NI	NI	NI

Notes:
1. The existing flows column identifies the flows generated by the Service Agency population identified in the table. The existing sewage treatment capacity is shown in parentheses.
2. "NI" indicates not identified.
3. "ADWF" indicates average dry-weather flow.
4. "mgd" indicates million gallons per day.
5. "gpd" indicates gallons per day.
6. "Veale Tract area" refers to the region defined by the Spread alternative development in the vicinity of the Veale Tract. The population associated with this area does not include the Bethel Island community.
7. "Unallocated population" refers to that portion of the total estimated population for each alternative scenario that was located outside of the various agency service boundaries.

ACCOMMODATING FUTURE GROWTH

This section presents a brief overview of sewer service agency plans to accommodate population growth projected by the County, as assigned to sewer service areas by Brown and Caldwell. Rough cost estimates were prepared based on service agency capital improvement plans or other cost estimates. These cost estimates are shown in Table 3-2 and are discussed in the following paragraphs. Costs include treatment, transport, and collection of sewage but do not include costs for local on-site sewer facilities that would be installed by developers. These costs will be included in the financial analysis prepared by Economic and Planning Systems.

In instances where there is no difference between the Composite and Spread Alternative population projections, costs are attributed only to the Composite Alternative. The cost for the Composite Alternative totals $205,029,000. The incremental cost for the Spread Alternative is estimated to be $66,579,000. The total estimated cost for sewer service capacity expansions to meet future development needs as defined in the two scenarios is $271,608,000.

Central Contra Costa Sanitary District

Central Contra Costa Sanitary District (CCCSD) is the largest sewer service agency in the County, serving approximately 350,000 people. The County traffic zone population projections for the CCCSD service area vary from population forecasts provided by CCCSD. The 1985 population difference can be attributed to a CCCSD population estimate of about 12,000 to 15,000 that utilizes septic tanks. This population was included as part of the CCCSD service population in the County traffic zone projections. In discussions with CCCSD, it was also noted that the CCCSD future service population projections take into account redevelopment and densification within their existing service area.

CCCSD has developed a very detailed capital improvement plan. The cost estimates presented in Table 3-2 are based on this plan but are modified so as to be applicable to the County traffic zone population projections. The capital improvement plan extends to the year 1996-97, corresponding to a population of 460,000 (roughly equivalent to the Spread Alternative population). Treatment plant costs were calculated on a per capita basis and allocated to the Composite and Spread Alternative growth scenarios.

CCCSD capacity expansions for their treatment plant and the collection system do account for increased demand resulting from development in the Dougherty Valley area (Spread Alternative development in east San Ramon). Unlike the treatment plant costs, however, the collection system costs can not be "staged" to meet the demands of discrete population levels such as the Composite and

Table 3-2 Existing and Projected Sewer Service Population Estimates in Contra Costa County

Sewer service entity		Cost for Composite alternative, dollars	Incremental cost for Spread alternative, dollars
Central Contra Costa Sanitary District	Transport	73,910,000	3,826,000
	Treatment/ disposal	22,799,000	23,926,000
Delta Diablo Sanitation District	Transport	8,044,000	5,873,000
	Treatment/ disposal	6,202,000	7,076,000
Stege Sanitary District	Transport	0	0
	Treatment/ disposal	0	0
West Contra Costa Sanitary	Transport	1,143,000	0
	Treatment/ disposal	0	0
Mountain View Sanitary	Transport	6,056,000	0
	Treatment/ disposal	3,162,000	0
Dublin-San Ramon Sanitary District	Transport	2,622,000	0
	Treatment/ disposal	2,758,000	0
Rodeo Sanitary District	Transport	0	0
	Treatment/ disposal	0	0
Crocket-Valona Sanitary District	Transport	0	0
	Treatment/ disposal	0	0
Oakley-Bethel Island Wastewater Management Authority	Transport	8,587,000	3,021,000
	Treatment/ disposal	23,733,000	7,440,000
Byron Sanitary District	Transport	0	0
	Treatment/ disposal	0	0
City of Richmond	Transport	0	0
	Treatment/ disposal	0	0
City of Hercules	Transport	2,351,000	0
City of Pinole	Treatment/ disposal	0	0

Notes: 1. Local on-site collection costs are not included in these cost estimates.
2. Estimated system rehabilitation costs that are needed in response to existing capacity deficiencies are as follows:

Central Contra Costa Sanitary District	$101,268,000
Stege Sanitary District	$ 5,244,000

Table 3-2 Existing and Projected Sewer Service Population Estimates in Contra Costa County (continued)

Sewer service entity		Cost for Composite alternative, dollars	Incremental cost for Spread alternative, dollars
City of Brentwood	Transport	11,089,000	1,175,000
	Treatment/ disposal	29,411,000	2,894,000
Discovery Bay	Transport	1,562,000	0
	Treatment/ disposal	1,600,000	0
Port Costa	Transport	0	0
	Treatment/ disposal	0	0
Veale Tract area	Transport	0	4,421,000
	Treatment/ disposal	0	6,927,000
Totals		205,029,000	66,579,000

Notes:
1. Local on-site collection costs are not included in these cost estimates.
2. Estimated system rehabilitation costs that are needed in response to existing capacity deficiencies are as follows:

Central Contra Costa Sanitary District	$101,268,000
Stege Sanitary District	5,244,000

3. "Veale Tract area" refers to the region defined by the Spread alternative development in the vicinity of the Veale Tract. The cost estimates associated with this area do not include sewer service associated with the Bethel Island community.

Spread Alternatives. The design of the interceptor pipeline system as provided for in CCCSD future planning is large enough to serve development in the Dougherty Valley area. The design of the system is independent of the "Ultimate" service population because inflow/infiltration influences the size to a greater extent than the population. Additional costs that are associated with the installation of a collection network in the Dougherty Valley area are based on Dublin San Ramon Services District cost estimates. The Composite Alternative trunk pipeline costs include 26,900 feet of pipeline facilities ranging in diameter from 8 to 27 inches. The Spread Alternative trunk pipeline costs include service to the Dougherty Valley area and includes nearly 70,000 feet of pipeline facilities ranging in diameter from 8 to 24 inches.

Delta Diablo Sanitation District

The Delta Diablo Sanitation District (DDSD) provides sewer service to the Cities of West Pittsburg, Pittsburg, and Antioch. The capital improvement plan obtained from DDSD has provisions for accommodating the 51 percent growth for the Composite Alternative and an additional 23 percent growth attributed to the Spread Alternative as projected in the County's scenarios. However, the County population projections are achieved at a more rapid rate relative to DDSD forecasts. Growth in DDSD is directly tied to growth is in the Cities of Pittsburg and Antioch. An annexation practice that is in operation in the County is such that there can be no annexation to these cities without a simultaneous annexation to DDSD.

The cost estimates for treatment plant expansion are based on a two-stage expansion. The two stages correspond roughly to the projected Composite and Spread Alternative populations. The collection system costs are made up of elements related to DDSD-owned major pipelines and trunk pipelines owned by the Cities of Pittsburg and Antioch.

Stege Sanitary District

The Stege Sanitary District is responsible for maintenance of the collection system within its district boundaries. Sewage is conveyed to and treated at an East Bay Municipal Utility District treatment plant located in Oakland, California. County and District population projections indicate that the service area is near buildout. The County projections suggest a decrease in total service population from 1985 to the forecast Composite Alternative population due to anticipated decline in average household size.

The system capacity deficiencies that have been identified are existing deficiencies and are therefore not attributed to future growth. Note, however, that an estimate for rehabilitation costs for the existing system is provided in Table 3-2.

West Contra Costa Sanitary District

The West Contra Costa Sanitary District (WCCSD) serves the City of San Pablo, the northern portion of Richmond, and parts of Pinole and El Sobrante. The WCCSD operates a treatment plant recently upgraded to 12.5 million gallons per day (mgd) average dry-weather flow (ADWF) with an existing wastewater flow of 7.5-mgd ADWF. Assuming a percentage increase in flows consistent with the projected population increase, the treatment plant has sufficient capacity to accommodate the Composite and Spread Alternative populations.

Most of the development anticipated to occur in the WCCSD service area is in-fill development and therefore would not require the installation of major transport pipelines. However, there are several areas in the eastern portion of the service area that constitute development requiring new facilities for sewage transport and collection. Costs for a major interceptor pipe line connecting these eastern service area development areas to existing facilities are included in the cost estimate presented in Table 3-2.

Dublin San Ramon Services District

The Dublin San Ramon Services District (DSRSD) service area is divided between Alameda County and Contra Costa County. The DSRSD treatment plant is currently undergoing the Stage 3B treatment capacity expansion. Estimated costs for this expansion were converted to a cost per mgd and then allocated on a per capita basis relative to the Composite Alternative projected population within the DSRSD Contra Costa County service area. These costs do include facility upgrade/improvement costs rather than just costs associated with capacity expansion and are therefore conservative.

Mountain View Sanitary District

The Mountain View Sanitary District (MVSD), serving a portion of Martinez, is completely enclosed within the Central Contra Costa Sanitary District service area. The long-range plan for MVSD consists of a staged treatment plant capacity expansion from 1.74 mgd to 2.4 mgd, and then to 3.2 mgd ADWF. MVSD estimates an ultimate buildout service population of 29,000. The County traffic zone population projections for the Composite and Spread Alternatives is only 18,378.

The treatment plant cost estimate to accommodate the County growth projection is based on treatment capacity expansion to 2.4 mgd. Based on calculated MVSD per capita generation of waste, this treatment capacity is adequate to accommodate the County projected growth.

The long-range plan also includes sewer system capacity expansions. There was some difficulty in differentiating between capacity expansion resulting from existing capacity deficiencies and new development. Based on a review of the County projected development data base and the map of the two scenarios, most of the costs for improvements included in the cost estimate can be considered to be due to new development.

Rodeo Sanitary District

There are no significant developments anticipated within the Rodeo Sanitary District service area. In fact, the County traffic zone population projections indicate a decrease in service population. In this analysis, the assumption is that the Rodeo Sanitary District will not serve development in the Franklin Canyon area. The design capacity of the treatment plant (1.14 mgd ADWF) is adequate to handle existing and projected populations. Currently, the ADWF is 825,000 gallons per day (gpd).

Crockett-Valona Sanitary District

The treatment plant that serves the Crockett-Valona Sanitary District (C-VSD) is jointly owned by C&H Sugar and C-VSD. C-VSD has been allocated a maximum of 0.3 mgd of a total treatment plant capacity of 2.69 mgd. The C&H Sugar wastewater flows range between 0.85 mgd and 1.25 mgd thereby resulting in excess treatment capacity of about 1.14 mgd. There are no treatment plant or collection system expansion costs determined for C-VSD as part of this analysis because of the insignificant level of projected growth.

In a discussion with a representative from C-VSD, it was noted that if development were to occur within the service area, the individual developers would be responsible for purchasing additional treatment capacity. Doubling the treatment capacity allocation was estimated to cost between $1 million to $1.5 million.

Oakley-Bethel Island Wastewater Management Authority

The Oakley-Bethel Island area is anticipated to undergo significant growth based on the County traffic zone population analysis of the two scenarios. The treatment facility located in Oakley is jointly utilized by the Oakley Sanitary District and the Bethel Island Community. Current flows are about 1.0 mgd with a total design capacity of 1.5 mgd.

Currently, Oakley-Bethel Island Wastewater Management Authority (O-BI) treated effluent is disposed of by means of a land disposal system. Land disposal may become impractical in the future for

O-BI and several other east County areas that are projected to undergo substantial growth. The reasons for this are discussed below:

1. Land disposal is an effective means of disposal for systems with relatively small flows. As total flow increases, the total land surface requirement increases and land costs may become prohibitive.

2. There is a high water table in the O-BI and other east County areas. The high water table effectively reduces the treatment capacity of the land thereby necessitating an increase in the total land surface area available for disposal.

Alternatives to land disposal include treatment facility upgrade to tertiary treatment and effluent water reuse or disposal via a surface water outfall. These alternatives and others would have to undergo a detailed analysis to determine the most cost-effective means of disposal.

As part of this sewer system cost evaluation, we have determined the total cost of effluent transport and outfall disposal in New York Slough. This system would be adequate to accommodate effluent generated from Composite and Spread Alternative population projects within O-BI, the City of Brentwood, the Bethel Island area, and the Veale Tract area. The total cost was converted to a per capita cost and allocated to the population projections for the County areas identified above. The costs are included in the treatment/disposal category in Table 3-2. Additional cost estimates for sewer system capacity expansions were based on studies done by Brown and Caldwell evaluating expansion costs for other similarly sized systems.

<u>Byron Sanitary District</u>

The Byron Sanitary District treatment system consists of a 40,000-gallon community septic tank with six evaporation/percolation ponds. Significant growth is not anticipated within the time frame of this study. No facility capacity expansions are planned.

<u>City of Richmond</u>

The City of Richmond sewage treatment system serves only a portion of Richmond. The growth that is anticipated within the City boundaries falls primarily within the service area of West Contra Costa Sanitary District.

The 1985 base case County traffic zone population estimates are fairly consistent with the Richmond service population estimate. However, the service agency anticipates an increase in population

of about 3,500 rather than the 1,000 person increase indicated by the County's projection by traffic zones. The existing treatment capacity (16 mgd ADWF) is adequate to accommodate either of these projected population increases. The existing ADWFs are about 6.5 mgd.

City of Pinole/City of Hercules

The City of Pinole operates a treatment facility which treats waste from a portion of the City of Pinole and the City of Hercules. Existing ADWFs are 2.4 mgd. The design capacity of the treatment plant is 4 mgd. The total capacity allocation is evenly divided between Pinole and Hercules. There is no room for expansion of the existing treatment facilities. In addition to the City of Pinole treatment facility, Hercules operates a small treatment plant with a design capacity of 0.3 mgd ADWF.

The growth projected in the Pinole portion of the service area is expected to remain within the 2-mgd treatment capacity limitation. However, according to City of Hercules representatives, there is some uncertainty with regard to quantifying growth in the Hercules area. Factors that will influence growth include:

1. Because there is a Pinole treatment plant capacity limitation of 2 mgd for the City of Hercules, extensive growth will require expansion of the Hercules treatment plant. Very preliminary estimates are an expansion to 1 mgd, although a greater capacity expansion may ultimately occur.

2. Hercules development plans include an industrial park. No decision has been made on the ultimate size of the industrial park which, by some estimates, may generate significantly greater than 1-mgd wastewater flow.

Because no final decisions have been made regarding development in Hercules and therefore the extent of the Hercules treatment plant expansion, the cost estimates presented in Table 3-2 are based on the County traffic zone population projections. The existing combined treatment capacity of Pinole/Hercules is 4.3 mgd ADWF. This is adequate to accommodate the County traffic zone projected Composite/Spread Alternative service population of 41,743. Therefore, costs for treatment plant expansion are not included in the total costs for sewer service for new growth.

There are two areas in the eastern portion of the service area which constitute new development anticipated to require installation of major transmission pipelines. The costs for transmission pipelines are based on 9,000 feet of 8-inch-diameter-pipe. These costs are included in Table 3-2.

Community of Port Costa

The community of Port Costa is located within the service area of County Sanitation District No. 5. The community septic system has a capacity of 33,000 gpd ADWF with current flows averaging 6,000 to 7,000 gpd. The community is bounded almost entirely by East Bay Regional Park property. Expansion opportunities are therefore limited. No significant growth is anticipated and there are no costs associated with the Composite and Spread growth scenarios.

Discovery Bay

Discovery Bay sewer service (County Sanitation District No. 19) is handled under contract by Delta Diablo Sanitation District. Sewage treatment at Discovery Bay, consisting of an oxidation ditch system, has a capacity of 800,000-gpd ADWF with existing flows between 400,000 and 500,000 gpd. Because the system has not consistently met state discharge requirements. Additional improvements to the system, including treatment capacity expansion to 1.2 mgd, are service demands of adequate to meet the sewer service demands of the Composite and Spread Alternative population projections. The cost estimate for sewer service in the Discovery Bay area is based on transportation and treatment capacity expansion to 1.2 mgd.

Brentwood

Consistent with several other east county areas, the City of Brentwood service area is projected to undergo some of the most extensive growth in the County based on the County land use/population scenario analyses by traffic zones. There are plans in the immediate future for construction of the first stage of a multi-staged expansion from the existing treatment capacity of 0.6 to 1.8 mgd. The ultimate design capacity is expected to be 5.4 mgd. The City of Brentwood's projections based on its General Plan do not reflect the rapid future growth projected in the Composite and Spread Alternative analysis and, so, do not contain estimates of costs needed to accommodate the County estimated growth. Utilizing studies done by Brown and Caldwell evaluating facility expansion costs for several other sewer systems, cost estimates were made for sewer facility expansions needed to accommodate population expansion to approximately 50,000 people. The treatment/disposal cost estimate includes a portion of the total cost of the transport and surface water outfall system for treated effluent disposal as described in the discussion on the Oakley-Bethel Island Wastewater Management Authority.

Veale Tract Area

The Veale Tract area is anticipated to experience substantial growth as part of the Spread Alternative development in east county. The total Spread Alternative population for the Veale Tract area is 14,738. In this analysis, we have not assumed expansion of any particular existing sewer agency to serve the Veale Tract area. The cost estimates for sewer service were based on studies done by Brown and Caldwell evaluating expansion costs for various communities. The treatment/disposal cost estimate includes a portion of the total cost of the transport and surface water outfall system for treated effluent disposal as described in the discussion on the Oakley-Bethel Island Wastewater Management Authority.

CHAPTER 4

STORM DRAINAGE

This chapter presents the storm drainage costs associated with development in accordance with the Composite and Spread Alternative scenarios that have been defined for the Contra Costa County (County) General Plan Review program. The flood control system within the County is discussed with respect to agency jurisdiction, design criteria, and basic flood control improvements. The location, nature, and extent of existing flooding problems are examined. The costs of needed flood control improvements are discussed with a distinction provided between the calculated local storm drainage costs directly associated with new development, the rough capital cost estimates of required regional flood control improvements, and levee rehabilitation costs.

STORM DRAINAGE SYSTEMS WITHIN CONTRA COSTA COUNTY

The following discussion identifies the various public agencies providing flood control protection within the County. Land developers are also discussed because they provide a significant portion of flood control improvements within the County. Lastly, the design criteria and basic types of flood control improvements are presented.

City and County Jurisdiction and Responsibilities

All public drainage systems within the incorporated County areas are under the jurisdiction of the local city government except for the facilities owned by the Contra Costa County Flood Control District. Also within the incorporated areas, only the city can require new developments to install adequate drainage as a part of the development process. In most cases, the cities have adopted development regulations and design criteria similar to those adopted by the County. However, the application of the regulations vary from city to city. Most cities submit proposed development plans within their city to the Flood Control District for comment. The Flood Control District's responses are implemented or discarded at the discretion of the city.

All public drainage systems within the unincorporated area are under the jurisdiction of the County except for the facilities owned by the Flood Control District. In the unincorporated areas, the County has the same responsibilities and authority as the

cities do in the incorporated areas. The Flood Control District also provides an advisory review of proposed development plans in the unincorporated County area.

It must also be noted that the city areas and the unincorporated County contain numerous natural watercourses, swales, and ditches which are privately owned. The cities and County have no jurisdiction over these facilities except to the extent that they have adopted ordinances to prevent private property owners from blocking the natural drainage flow.

Flood Control District Jurisdiction and Responsibilities

- Development and maintenance of hydrology standards.
- Advisory comments on matters relating to storm drainage.
- Development of regional drainage plans.
- Construction of drainage systems on a fund-available basis.
- Maintenance of selected major drainage facilities on a funds-available basis.

The state legislation creating the Flood Control District sets forth the District's duties and responsibilities. The legislation establishes the Flood Control District, in most cases, as an advisory agency with each city, having veto power over District activities within their jurisdiction. The Flood Control District has adopted drainage plans providing for the construction or maintenance of regional drainage systems. In some cases, the plans provide for both construction and maintenance.

The funding for Flood Control District projects comes from a multitude of sources, including developer drainage fees, annual benefit assessments, property taxes collected in specific areas, federal flood control programs, the State Flood Control Subvention Program, assessment districts, and other local governments under joint projects.

Federal-State Flood Control Programs

Storm drainage improvements are frequently too costly to be financed solely by local communities. In the past, the Flood Control District and cities have approached state or federal agencies for financial assistance for extensive flood control projects. The largest outside contributors have been the U.S. Army Corps of Engineers (Corps) and the Soil Conservation Service (SCS).

Various California State programs have also financed flood control projects within the County. The most active agency has

been the Department of Water Resources (DWR). The DWR through the federal-state flood control programs has borne a significant share of the nonfederal costs associated with providing rights-of-way and relocations necessary for implementation of Corps and SCS projects. More recently, the state has approved legislation for a $120 million program to fund levee improvements for several Delta islands including Bethel Island.

The reliance upon state or federal agencies to subsidize local flood control projects has its benefits and costs. Such financial assistance often represents the deciding factor as to whether very large, expensive projects can be built. However, the funding process is very dependent on the budgetary situation in Sacramento or Washington, D.C.

Developer-Financed Drainage Improvements

Land developers represent a significant source of drainage infrastructure. With the exception of the federal-state flood control programs and several isolated drainage areas that receive property tax, almost all of the existing drainage infrastructure has been constructed through the development process. Annually, the development process funds millions of dollars in drainage infrastructure, even though many developments succeed in developing without contributing their fair share. The legal restrictions on developing drainage fees and the scattered nature of development has allowed some developments to skirt their responsibilities while others have been forced to fund more than their share. The design and construction of developer-provided flood control improvements must pass the review of the appropriate city or county agency requiring the improvements.

The previous discussion shows the varied flood control funding sources used within the County. In summary, County and city governments have insufficient funding to construct the needed flood control projects. Some flood control projects are built by developers, while others are funded by developers (via storm drainage fees) but constructed by the Flood Control District. Some large-scale projects are constructed with financial assistance from state or federal agencies. Lastly, other necessary projects remain unbuilt because the financial sponsorship is lacking.

Adopted Design Criteria

Storm drainage improvements are designed according to natural watershed boundaries. The Flood Control District has divided the County into approximately 25 watershed areas according to topography. These watershed areas have been further divided into approximately 185 drainage subareas, as shown on the Flood Control District's drainage area map (Drainage Entity Boundaries and Flood Control Channels, R575).

The design capacity of storm drainage systems depends upon the size of the watershed areas being served. The County follows design criteria established by the Contra Costa County Subdivision Ordinance Code. The various city engineering offices generally follow the same criteria. For example, drainage areas less than 1 square mile in area require minor drainage facilities capable of carrying 10-year frequency storm events. Secondary drainage channels and conduits are required for drainage areas between 1 and 4 square miles in area; these storm drainage systems must be adequately sized to convey 25-year frequency storm events. Drainage areas larger than 4 square miles must provide major drainage channels and conduits sufficiently large to carry 50-year frequency storm events.

The peak runoff quantity (design capacity) is dependent on several factors: the amount of rainfall; the storm duration; the efficiency of the upstream drainage systems; the size, shape, and steepness of the watershed; and the amount of impervious surfaces in the watershed. Paved surfaces and buildings transmit more runoff than earth surfaces. Impervious surfaces also change the timing of flood flows through flood control channels. The increased runoff and peak flood flow timing changes represent important factors affecting the storm-carrying capacity of natural creeks or flood control channels.

Types of Flood Control Improvements

Flood control improvements vary in shape, size, and character. The improvements vary from a 15-inch-diameter storm drain conveying 2 cubic feet per second to a major channel, like Walnut Creek, which conveys 25,000 cubic feet per second. Detention basins vary from 15 acre-feet to more than 3,000 acre-feet behind Marsh Creek Dam. The spectrums of types of facilities varies from small to large and from very structured, engineered to environmentally sensitive. Some of the types of facilities used are:

- Storm drain pipes and conduits
- Concrete-lined channels
- Earth channels
- Artificial floodplains
- Natural watercourses
- Detention basins

FLOOD CONTROL IMPROVEMENT COSTS

This section presents the estimated flood control improvement costs for Contra Costa County. There are three categories of storm drainage costs that are discussed below. The first category is

denoted development drainage control costs and refers to costs that are required to mitigate potential flooding and erosion resulting from new development and to ensure that the redevelopment is adequately protected from future flooding and erosion. Within the context of this evaluation, the Composite and Spread Alternative developments constitute new development in the County. The second category of costs is denoted missing flood control improvement costs and refers to the costs that are required to mitigate existing County flooding problems. The third category entails levee improvements to Bethel Island, Hotchkiss Tract, and Veale Tract in the North Delta area.

The three categories of costs are not easily separated. Many of the facilities required under "missing flood control improvements" will be installed under the first category "development drainage control costs" because meeting the mitigation ordinance code requirements on new developments will require installing improvements in areas of inadequate drainage. Therefore, establishing the fair cost share for new developments is a difficult task. Based on recent experiences of the Flood Control District in the formation of new drainage areas for relatively undeveloped areas, they have determined that a complete drainage system including minor, secondary, and major channel improvements costs approximately $0.35 per square foot of impervious surface.

The development drainage control costs were calculated by applying the above $0.35 per square foot of impervious surface fee to the projected development acreage. Table 4-1 shows that a total of $333 million in developer drainage improvements would be required for projected Composite and Spread Alternative development. The missing flood control improvement costs were determined through discussions with the Flood Control District, the Corps, and other agencies involved in flood control activities. A very brief description of flood problems within the different watershed areas is provided below. Such improvements total between approximately $500 and $800 million, as shown in Table 4-2. A portion of these missing flood control improvement costs can be fairly assessed to new developments because such development intensifies the regional storm drainage inadequacies. The levee rehabilitation costs are based upon a 1981 DWR report, Delta Levees Investigation, that discussed needed Delta levee rehabilitation based on existing land uses.

Storm Drainage Costs Associated With New Development

The local storm drainage costs calculated in this report represent those local flood control improvements necessary to mitigate the effect of urbanization upon local creeks and flood control channels and the local "collect-and-convey" costs involving storm drains in excess of 24 inches in diameter. The types of flood control improvements would be the same as those required for

Table 4-1 Cost Estimates for Flood Control Improvements in Contra Costa County to Serve the Composite and Spread Alternatives

Watershed		Development acreage of alternatives		Development drainage control costs	
				November 1987 dollars	
Number	Name	Composite	Spread	Composite	Spread
1	Marsh Creek	6,427	4,599	49,093,294	31,748,032
2	Kellogg Creek	-	78		1,205,880
3A	Walnut Creek (east of creek)	4,091	254	17,315,041	1,183,386
3B	Walnut Creek (west of creek)	3,681	94	17,947,259	740,003
4	Lower Mt. Diablo Creek	868	77	12,338,994	568,029
4A	Upper Mt. Diablo Creek	898	-	2,724,362	-
5	Alhambra Creek	322	-	1,744,832	-
6	San Pablo Creek	3,001	109	28,321,121	1,125,567
7	Wildcat Creek	122	32	1,324,112	494,720
8	Upper Rodeo Creek	572	-	6,268,705	-
8A	Lower Rodeo Creek	57	-	876,195	-
9	Upper Pinole Creek	5	-	23,295	-
9A	Lower Pinole Creek	403	-	1,725,330	-
10	Willow Creek	561	1,558	5,268,639	12,141,776
11	East Antioch Creek	2,594	636	18,405,306	6,054,799
12	West Antioch Creek	453	-	3,574,162	-
13	Kirker Creek	693	-	7,771,073	-
14	Alamo Creek	2,351	5,261	14,635,470	39,445,570
21	Richmond area south of Wildcat Creek	381	-	4,013,649	
22	Refugio Creek Hercules	1,081	-	9,294,884	
23	Port Costa area	86	-	1,151,734	
24	East Martinez area	144	-	1,460,151	
26	Pittsburg	151	-	2,334,460	
27	Oakley area	928	-	10,453,746	
28	North Delta area	922	1,805	6,263,082	9,437,098
29	South Delta area	6	-	50,988	
30	Moraga/Rheem area	954	22	4,252,414	196,327
Total		31,752	14,525	228,632,298	104,344,187

Notes: 1. "Development drainage control costs" refer to those flood control expenditures exclusively associated with and provided by new developments.

2. The Spread Alternative cost estimate is an incremental cost associated only with new development in the Spread Alternative.

3. "-" indicates that development acreage or development drainage control costs were not identified.

Table 4-2 Partial List of Missing Drainage Infrastructure

Zone	Name	Estimated cost, million dollars	
	Major channels and 50 percent of secondary channels		
1	Marsh Creek System - capacity	20	28
2	Kellogg Creek - capacity	3	6
3B	San Ramon Bypass by Corps of Engineers - capacity	10	12
3B	Upper Pine Creek by Corps of Engineers - capacity	3	3
3B	Upper Pine Creek by Flood Control District - capacity	0	1
3B	Galindo Creek Bypass, d/s Treat - capacity	37	10
3B	Galindo Creek Basin at Ygnacio - capacity	4	7
3B	Walnut Boulevard Drain - capacity	1	2
3B	Sans Crainte Channel - capacity	2	5
3B	Miranda Creek - capacity	1	2
3B	Stone Valley Creek - capacity	2	4
3B	San Ramon Creek - Chaney to Livorna - capacity	5	7
3B	San Ramon Creek - d/s of Greenbrook - capacity	1	2
3B	Green Valley Creek and tributaries - capacity	5	8
3B	Sycamore Creek, d/s of Blackhawk Road - erosion	1	2
3B	San Catanio Creek - erosion	2	3
3B	Tice Creek - capacity	3	5
3B	Las Trampas Creek - erosion	8	16
3B	Reliez Creek - erosion	2	4
3B	Murderers Creek - capacity	7	10
3B	Grayson Creek East Branch - capacity	9	12
3B	Grayson Creek West Branch - capacity	1	1
3B	Pacheco Creek - capacity	1	1
3B	Bollinger Creek - erosion	1	2
4	Mt. Diablo Creek, lower-capacity	2	5
4	Mt. Diablo Creek, upper-capacity	15	20
5	Alhambra Creek - erosion and capacity	20	35
6	San Pablo, d/s of I-80-capacity	18	25
6	San Pablo, u/s of I-80-erosion and capacity	2	4
6	San Pablo, u/s of reservoir-erosion and capacity	2	20
6	Wilke Creek - erosion and capacity	2	3
6	Appian Creek - erosion and capacity	3	5
6	Castro Creek - erosion	1	1
7	Wildcat Creek, d/s of Vaile - capacity	17	22
7	Wildcat Creek, u/s of Vaile - erosion	1	2
8	Rodeo Creek, u/s of AT&SF - capacity and erosion	1	2
9	Pinole Creek, u/s of I-80 - capacity and erosion	4	6
11	East Antioch - capacity	12	17
12	West Antioch - capacity	10	12
13	Kirker Creek - capacity and erosion	20	30
14	Alamo Creek - capacity and erosion	7	11
14	South San Ramon and tributaries - capacity and erosion	1	1
	El Cerrito, El Sobrante, Richmond, North Richmond, San Pablo, Montalvin Manor, Rodeo, Crockett, Martinez, Pacheco, Concord, Clayton, Pleasant Hill, Walnut Creek, Orinda, Lafayette, Alamo, Danville, San Ramon, West Pittsburg, Pittsburg, Antioch, Oakley, Brentwood, Byron	200	400
	Total	467	774

[a]The costs listed above are rough estimated costs of outstanding problems. Detailed estimates and reports documenting the above do not exist. This list is provided only as a means of portraying the scope of missing or inadequate (capacity or erosion) drainage infrastructure.

regional flood control improvements, e.g., channel improvements, bypass systems, and detention basins. However, such local flood control improvements are a direct result of future development.

Determination of an Appropriate Storm Drainage Fee. The varying topography, development extent, and existing flood problems make it impossible to determine a uniform storm drainage fee which would provide for all needed flood control improvements within the County. However, this report has determined an applicable minimum fee derived from an evaluation of those County areas with negligible existing flood problems and a tremendous amount of projected growth. For such areas, a storm drainage planning estimate of $0.35 per square foot of created impervious surface area ($0.35 planning estimate) was used. This $0.35 planning estimate was applied to all projected development areas. Funding problems will arise, however, in those new developments having less projected development to share the costs of flood control improvements or areas having preexisting flooding problems. These latter areas may not generate sufficient funds from assessment of the basic $0.35 planning estimate to cover the full cost of development storm drainage improvements.

The basic $0.35 planning estimate used in this report was used to calculate 14 different drainage planning estimates according to the impervious surface created by each of the 14 land use categories. The smallest estimate ($2,602 per gross acre) was calculated for very low density, single-family homes. The largest estimate ($15,460 per gross acre) was determined for commercial and industrial developments. Such per-acre planning estimates were multiplied by the land use acreages to determine the costs of required storm drainage systems.

There are approximately 25 watershed basins within the County. These watersheds are subdivided into approximately 185 drainage areas. Of these drainage areas, about one-fifth of them have established drainage fees. These fees range from $0.05 to $0.38 per created square foot of impervious surface. A few, older drainage fees charge the same per-acre fee regardless of land use type. Such fees range from $360 to $13,700 per acre. Many of the presently assessed drainage fees are considerably lower than $0.35. Flood Control District officials have indicated that the currently charged drainage fees would not always provide adequate storm drainage systems at today's prices. They note that the most recently adopted drainage fees have been in the $0.34 to $0.38 range. When older drainage fees are reevaluated, they are usually raised to about a $0.35 fee because of inflation or land use density changes.

The District's Drainage Entity Boundary Map (R575) indicates that drainage fees are not assessed in many County locations. Fees can only be assessed for those areas in which the District has

designed a flood control system adopted by the County Board of Supervisors. The Flood Control District does not have sufficient staff to complete this lengthy design process for all County areas. Therefore, the Flood Control District has chosen to concentrate its efforts on establishing drainage areas for those city and County areas experiencing rapid development. Because new developments in unestablished drainage areas cannot be assessed drainage fees, such developments represent a literal financial loss to the County. Such unassessed areas contribute to storm drainage inadequacies without contributing financially to their solutions.

As discussed earlier, flood control costs for newly developing areas would be less than those costs associated with similar flood control improvements in an existing developed area. New areas experiencing considerable development can spread the cost of flood control improvements over a large number of new developments. This results in a lower unit cost per acre than can be charged to similar developments occurring in developed areas experiencing limited new development. Major channel improvements are similarly more economical in new areas because construction procedures are not hindered by existing structures such as buildings, roadways, or utility lines. Land costs are also generally higher in developed areas than in developing areas.

Proposition 13 funding restrictions generally dictate that only new developments be charged the costs of infrastructure improvements such as storm drainage systems. Small-scale developments in previously developed areas may have to pay more than the basic fee in order to fund required flood control improvements needed to solve existing flooding problems as well as future flooding problems resulting from new development. Such costs would have to be determined on a case-by-case basis. Table 4-2 provides estimates of the cost of additional major flood control improvements for the various Flood Control District watershed areas.

<u>How Local Storm Drainage Costs Were Determined</u>. A per-acre drainage planning estimate was calculated for each of the 14 land use categories based upon the amount of impervious square feet created multiplied by the basic $0.35 drainage planning estimate. The acreage totals for each of the 14 land use categories were determined for the 185 drainage subareas in the 25 watershed basins. Since the land use projections for the scenarios were originally provided on the basis of traffic zones, it was necessary to regroup the data into watershed basins. Such watershed boundaries were determined according to the District's R575 map.

Determination of the 14 different storm drainage planning estimates required several assumptions regarding land use densities. These assumptions are (1) in order to calculate the amount of impervious surface created, the single-family very low density land use category was assumed to have 0.75 homes per acre

(2) the Flood Control District assumes different impervious surface areas for subdivision development as compared to small-scale development occurring on individual lots within existing developed areas. Since there was no way to ascertain which type of development was represented within the provided land use projections, this report applied the more extensive impervious surface figures associated with subdivision development; (3) the Flood Control District's impervious surface schedule charges drainage fees with respect to the net acreage of the land being developed. The projected land use acreages by traffic zone, reflect gross acreage figures as they include public areas such as streets, median strips, mini parks, etc. It was therefore necessary to convert costs per net acre to costs per gross acre.

These three assumptions permitted the calculation of the 14 different planning estimates charged per acre of development. Once the 14 different planning estimates were determined, it remained to determine the local flood control costs attributable to the Composite and Spread Alternative development scenarios. These costs were determined by multiplying the land use acreages by the appropriate planning estimate per acre. In this manner, the flood control costs were determined for 185 drainage subareas as well as for 25 watershed basins. Table 4-1 lists the local storm drainage costs for both the Composite and Spread Alternative developments with respect to the different watershed basins.

Missing Flood Control Improvement Costs Required by Existing Flood Problems

The second category of flood control costs that is discussed in this section is missing flood control improvement costs associated with existing flooding problems. In numerous County areas, inadequately sized flood control systems have resulted in flooding problems. This discussion lists those major flood-prone areas and provides rough capital cost estimates for the drainage systems proposed as solutions to these problems. Table 4-2 is a more complete yet still partial listing of missing drainage infrastructure in the County. Although the present flood problems are directly attributable to inadequate drainage systems provided by nature and past developments, future development will further aggravate the flooding problems. Some of the projects in the category of missing flood control improvements are presented with respect to their watershed boundaries. Drainage areas are subsets of the larger watershed basins.

Walnut Creek Watershed Area Number 3B. The downstream portion of Tice Creek experiences extensive local flooding; upstream areas immediately adjacent to the creek are also subject to flooding. The proposed $4 million remediation project entails the construction of a 60-acre detention basin plus the construction of a 4,600-foot bypass pipe system.

The Flood Insurance Rate Maps also show flooding along the length of Pine Creek. The Corps is presently completing channel improvements on Upper Pine Creek. This $7 to 8 million project is scheduled for completion in the fall of 1989. The Flood Control District plans future improvements further upstream toward Ygnacio Valley Road.

The Flood Control District has developed a $1 million earth channel improvement project for Green Valley Creek from Highway 680 upstream to the first crossing of Diablo Road. The city council of Danville must approve this project before it can be submitted to the Corps. Improvements farther upstream will also be necessary.

The Corps is presently completing Phase VIII of the Walnut Creek project, the San Ramon Bypass of downtown Walnut Creek. The third stage of Phase VIII has an estimated cost of $5 million and will begin construction in late 1988.

The Flood Control District has adopted a drainage plan for improvements to Grayson and Murderer's Creeks. Drainage Area 46 has been established to collect a $0.38 drainage fee. This fee will generate an estimated $2.25 million. The Flood Control District has requested that the Corps evaluate this project to determine if it qualifies for federal construction.

Mt. Diablo Creek Watershed Numbers 4 and 4A. The Flood Control District has submitted a proposed $16 million project to the city councils of Concord and Clayton. This flood control project, if approved, would provide improvements along Mt. Diablo Creek from Bailey Road to Kirker Pass. Funding for implementing the project has not been developed.

Alhambra Creek Watershed Area Number 5. Flooding occurs in downtown Martinez and along the length of Alhambra Creek from the Southern Pacific Railroad tracks upstream towards Hill Way. Coastal land adjoining Suisun Bay also appears on the Flood Insurance Rate Maps.

The Corps prepared two different creek improvement proposals for flood-prone Alhambra Creek during the 1970s. Both plans were rejected by city councils anxious that flood control improvements would spur development in the Upper Alhambra Creek Watershed area. The most recent proposal (of 1979) included three alternatives ranging in cost from $6 to $40 million. In November 1987 dollars, this price range is equivalent to $9 to $60 million. The Flood Control District is planning to explore other alternatives featuring upstream detention basins and a smaller downstream bypass pipe.

San Pablo Creek Watershed Area Number 6. San Pablo and Wildcat Creeks share the same floodplain so the Corps has designed one $37 million flood control improvement plan to improve both creeks. As of November 1987, only $2.6 million of the total had been spent.

Flood problems also exist upstream on San Pablo Creek near the Highway 24 crossing in Orinda. Although the Orinda flood area does not appear on provided Flood Insurance Rate Maps, downtown Orinda is susceptible to flooding. The concrete box culvert at the Orinda Village Shopping Center is inadequate for 100-year flood flows. The recently incorporated City of Orinda plans significant flood control improvements in the near future. The city council will soon be asked to adopt a $0.35 drainage fee to fund a study of local flood control needs. A considerably larger amount of money will presumably be required later to fund the actual flood control improvements.

Wildcat Creek Watershed Area Number 7. The Flood Insurance Rate Map shows flooding along the entire length of Wildcat Creek contained within Wildcat Canyon Regional Park. However, the District considers down-cutting and erosion within the two adjoining regional parks (Wildcat Canyon and Charles Tilden) to pose more significant problems than does flooding.

A localized flooding problem also occurs in downtown San Pablo where the Southern Pacific Railroad tracks cross Wildcat Creek. Further downstream, the estuary area of Wildcat Creek is subject to localized flooding. The costs of improvements to Wildcat Creek are discussed in the preceding paragraphs about San Pablo Creek.

East Antioch Creek Watershed Area Number 11. Extensive flooding occurs along the San Joaquin River shoreline, especially in the swampy areas north of the A.T.& S.F. railroad tracks or downstream of Lake Alhambra. The two creeks which converge at Lake Alhambra also flood upstream of the lake. Bidwell School lies within the western creek's flooded area. The eastern branch floods from Oakley Road downstream to Lake Alhambra.

The Flood Control District has designed a comprehensive flood control project for the East Antioch Creek watershed area. The County Board of Supervisors established Drainage Area 56 which assesses a $0.34 drainage fee of all new developments. This $30 million project includes tidal barriers, 4 detention basins, a silt basin, extensive channel improvements and approximately 110,000 feet of concrete pipes. The District has not planned on the Corps participating in this project as the $0.34 drainage fee is expected to generate sufficient revenue.

West Antioch Creek Watershed Area Number 12. Flooding occurs in the downstream reaches of Markley Canyon Creek and West Antioch Creek. The Flood Control District has prepared a plan of

improvement for a $6 to $7 million project to provide 100-year flood protection from the bay upstream to the Southern Pacific Railroad tracks. This project, if implemented, will remedy the flooding situation occurring at the confluence of West Antioch and Markley Creeks. The Flood Control District has submitted an application to the Corps for this project.

Kirker Creek Watershed Area Number 13. Flooding occurs upstream of Highway 4 because of an undersized culvert and a roadway traffic barrier. These structures cause water to back up behind the highway and nearby Southern Pacific Railroad tracks. This impounded water flows down into, and fills, the highway underpass.

Inadequate channel capacity downstream has caused extensive localized flooding at the U.S. Steel and Dow Chemical plants. The flood control channel on the north side of the Pittsburg-Antioch Highway is inadequate for all storm events. During almost every severe storm, flooding occurs along the highway.

The City of Pittsburg commissioned a study which recommended a $6.75 million project to remedy the watershed's flooding problems. This project, as designed, will only provide flood protection for 10-year storm flows although the watershed area is almost 15 square miles in extent. The city's assessed drainage fees for this project are considerably less than those that would be assessed by the 35 cent planning estimate schedule. Very rough estimates to upgrade the Kirker Creek channel improvements to provide 100-year flood protection indicate that the total project cost would be approximately $10 million.

Alamo Creek Watershed Area Number 14. The three flood zones in the Alamo Creek watershed area all lie within the City of San Ramon. The Flood Insurance Rate Maps show an extensive flood-prone area adjacent to the South Branch of San Ramon Creek. The City of San Ramon has constructed several channel improvements in this 10,000-foot stretch of the creek. Such improvements from Alcosta Boulevard south to the Alameda County line are now being studied with the intent of revising the Flood Insurance Rate Maps. The third flood-prone area consists of a thin ribbon of floodplain immediately adjacent to the main branch of Alamo Creek just north of the County line. Improvements for this reach of the creek are being incorporated into the Flood Control District's proposed Drainage Area 101A.

Refugio Creek Watershed Area Number 22. The flood situation within the Hercules area is not as extensive as the Flood Insurance Rate Map indicates. Areas upstream of Highway 880 have generally been improved by developers. Downstream of the highway there exists a 250- to 300-acre site which is susceptible to flooding. The City of Hercules has already incorporated this future industrial area into an assessment district. Landowners within this

assessment district will finance a $3.5 million project to provide flood control improvements from the bay upstream to San Pablo Avenue.

Levee Improvement Costs

The third category of flood control costs is levee improvements for the North Delta area including Bethel Island, Hotchkiss Tract, and Veale Tract. All three areas are at risk to inundation caused by levee failures. A December 1982 DWR publication, Delta Levees Investigation, states that without the recommended rehabilitation the statistical frequency of levee failure per 100 years for unimproved Bethel Island, Hotchkiss Tract, and Veale Tract are 0.20, 2.80, and 12.09, respectively. This report provided 1981 capital costs for construction of levee repairs to the three areas. In November 1987 dollars, Bethel Island levee improvements would cost $39.1 million, or $11,105 for every acre on the island. Hotchkiss Tract would require $8.6 million in levee improvements, or $2,590 per acre. Similarly, Veale Tract improvements (in 1987 dollars) would cost $5.3 million, or $4,113 per acre. Such levee improvement costs would be in addition to necessary storm drainage construction costs (assumed in this report to equal $0.35 per square foot of created impervious surface.) Maintenance of these levee systems would require an annual, per acre fee of $82 for Bethel Island, $20 for Hotchkiss Tract, and $19 for Veale Tract.

The DWR report states that the envisioned levee rehabilitation program would result in a probability of flooding on all islands of less than once in a 100 years. The report warns, however, that "the Department believes that most islands especially those below sea level, would not be suitable for urbanization."[1] United States Geological Survey maps show that the land surface elevations of Bethel Island and Hotchkiss and Veale Tracts vary between sea level and minus 10 feet. The levee rehabilitation costs presented in the previous paragraph were estimated with respect to existing land uses. If the extensive urbanization envisioned by the Composite and Spread Alternative scenarios were to occur, more extensive levee fortifications and correspondingly increased costs may be required.

The storm drainage inadequacies discussed above have been determined from conversations with District and city flood control officials and from consultation of various federal Flood Insurance Rate Maps. Flood Control District officials provided extensive information regarding current flooding problems and the corresponding flood control solutions proposed by the District.

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[1]Department of Water Resources Bulletin 192-82, Delta Levees Investigation, p. 78.

Additional information was obtained from a 1986 Federal Emergency Management Agency flood insurance study of the unincorporated areas of Contra Costa County.

The Flood Insurance Rate Maps provided for this study did not always accurately portray current flood-prone areas. Several cities such as Antioch, Danville, Hercules, and Pinole have performed necessary flood control improvements which have not been incorporated into the floodplain maps. This means that in some instances areas are incorrectly shown to lie within the 100-year floodplain. In such a situation the city or county provides waiver letters to property owners whose properties are incorrectly labeled as being within the 100-year floodplain. Such a waiver letter would be necessary in order to procure certain loans as well as to avoid required flood insurance premiums.

SUMMARY

Table 4-1 provides the development drainage control improvement costs associated with Composite and Spread Alternative development and the additional major regional flood control costs associated with existing flooding problems. The total development drainage control cost for the Composite Alternative scenario equals $187,068,273. The incremental cost estimate for the Spread Alternative storm drainage improvements amounts to $84,240,179. These figures were determined by multiplying the different land use acreages by the respective drainage planning estimates resulting from calculation of a $0.35 cent fee per square foot of created impervious surface. These planning estimates, if charged to all new developments, would fund the basic development drainage controls necessitated by the development. New construction would thus pay its share of needed local storm drainage improvements, i.e., those improvements necessitated solely because of new development.

The missing flood control improvements listed in Table 4-2 yield a total sum ranging from approximately $500 to $800 million. This sum includes the costs of levee improvements for the three Delta islands. In some areas, the storm drainage fees assessed new developments can contribute significantly to the mitigation of existing flooding problems. In other areas, significant outside financing would be necessary because new developments cannot by themselves fund much of the necessary flood control improvement costs.

ACKNOWLEDGMENTS

We acknowledge the Contra Costa County Flood Control and Water Conservation District for the invaluable assistance that they provided during the preparation of this section.

APPENDIX A

WATER SERVICE
REFERENCES AND CONTACTS

APPENDIX A

WATER SERVICE
REFERENCES AND CONTACTS

East Bay Municipal Utility District

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   Mr. Karl Stinson, EBMUD

Contra Costa Water District

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Brentwood

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   Contacts: Randy Dewante, Dewante & Stowell Consulting Engineers
   John Jones, Director of Public Works, City of Brentwood
   Bob Selders, Planning Director, City of Brentwood

Byron and Discovery Bay

Contacts: Fred Fallon, DeWante & Stowell Consulting Engineers
Bill McDonald, Delta Diablo Sanitation District
Elmer Schaal, Contra Costa County Public Works Department
Ron Tsugita, Delta Diablo Sanitation District

APPENDIX B

SEWER SERVICE
REFERENCES AND CONTACTS

APPENDIX B

SEWER SERVICE
REFERENCES AND CONTACTS

Central Contra Costa Sanitary District

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Contacts: Russell Lewitt, CCCSD
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Contact: Dave Contreras, Sanitary District Manager

Rodeo Sanitary District

Contact: David Beasley, Rodeo Treatment Plant Superintendent

Crockett-Valona Sanitary District

Contacts: Arthur del Agostino, Secretary for the Board of Directors, Crockett-Valona Sanitary District

Jake Schpak, General Manager of Engineering, C & H Sugar

Oakley-Bethel Island Wastewater Management Authority

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Contacts: Dave Bower, Oakley Sanitary District

Elmer Schaal, Contra Costa County Department of Public Works

Byron

Contact: Rene Fuog, Cregan and D'Angelo Consulting Engineers

City of Richmond

Contact: Henry Tingle, Superintendent, City of Richmond

BROWN AND CALDWELL
CONSULTING ENGINEERS

September 25, 1989

Mr. Douglas Duncan
Duncan and Jones
2161 Shattuck Avenue
Berkeley, California 94704

11-3182-01/7

Subject: Contra Costa General Plan Update
Additional Alternative Evaluation

Dear Mr. Duncan:

In accordance with our agreement dated September 7, 1989, we are pleased to submit our report, "Alternative Evaluation for Water, Sewer, and Storm Drainage Infrastructure Requirements in Contra Costa County". This report is an addendum to our January 1989 report. We have revised our water and wastewater cost estimates for the five alternatives you provided to us in July 1989. The storm drainage costs are unchanged because the plans of the Contra Costa County Flood Control District are not affected by the magnitude of the land use differences between these alternatives. Our evaluation includes an investigation of land disposal of wastewater in East County. Land disposal is feasible and will save some money in the Brentwood area. If you have any questions, please call me.

Very truly yours,

BROWN AND CALDWELL

William O. Maddaus

William O. Maddaus
Project Manager

WOM:ljk
Enclosures

cc: Mr. Jim Miller, Brown and Caldwell
Mr. Denis O'Malley, Brown and Caldwell
Mr. John Nyznyk, Brown and Caldwell
Mr. Dennis Barry, Contra Costa County

ALTERNATIVE EVALUATION FOR WATER, SEWER, AND
STORM DRAINAGE INFRASTRUCTURE REQUIREMENTS

ADDENDUM NO. 1
TO
EVALUATION OF WATER, SEWER, AND
STORM DRAINAGE INFRASTRUCTURE REQUIREMENTS -
COMPOSITE AND SPREAD ALTERNATIVES
dated JANUARY 1989

REGISTERED PROFESSIONAL ENGINEER
WILLIAM O. MADDAUS
NO. CE23648
Exp. 12.31.89
CIVIL
STATE OF CALIFORNIA

SEPTEMBER 1989

BROWN AND CALDWELL

INTRODUCTION

This document is an addendum to the revised January 1989 report prepared by Brown and Caldwell entitled "Evaluation of Water, Sewer, and Storm Drainage Infrastructure Requirements - Composite and Spread Alternatives." Since preparation of the revised January 1989 report, the alternative growth scenarios identified as part of the General Plan Review have undergone revision. For the purposes of water and wastewater infrastructure needs, the revisions entail modification of the Composite and Spread alternative growth scenarios and expansion to include three additional alternative growth scenarios (Preferred alternative, Urban Intensification alternative, and Transfer alternative). Details regarding the various alternative growth scenarios are presented elsewhere.

The objective of this addendum is two-fold:

- Briefly evaluate land treatment as a disposal option for treated wastewater in East Contra Costa County (County) including considerations with regard to technical feasibility and cost; and

- Update the cost estimates for meeting the water and wastewater infrastructure needs that were generated as part of the revised January 1989 report and expand the estimates to encompass the three additional alternative growth scenarios.

There are no new issues related to water supply and flood control that were not adequately addressed in the January 1989 report.

TREATED WASTEWATER DISPOSAL IN EAST CONTRA COSTA COUNTY

Each of the alternative growth scenarios has projected significant growth in East County. East County sewer service entities will be faced with developing new systems or expanding existing systems for the disposal of treated wastewater. Two alternatives that are available to East County for the disposal of treated wastewater are land disposal and surface water discharge. The various East County service entities will pursue one or a combination of these two options based on their particular needs and localized environmental conditions.

To acquire discharge rights for either disposal option, the service entity must submit to the Regional Water Quality Control Board (RWQCB) a Report of Waste Discharge (RWD) and an environmental impact report. These documents summarize potential environmental impacts that may occur as a result of wastewater discharge and propose measures to mitigate adverse impacts should they occur. In addition to a review of the proposal on the basis of technical feasibility, the RWQCB also considers cost comparisons between various alternative disposal schemes. The review process includes provisions for public review and comment.

In the following sections, we present a brief discussion regarding the major considerations related to selection of a particular disposal option. Disposal area sizing criteria and cost estimates are presented for the land disposal options. A summary is also presented for each of the East County service entities with respect to the issue of wastewater disposal.

Land Disposal

Land disposal of treated wastewater consists of application of the wastewater onto land. As treated wastewater percolates through the soil matrix, it is subjected to physical, chemical, and biological mechanisms of contaminant removal resulting in an improvement in the quality of the final effluent. Vegetative uptake prior to percolation through the soil matrix is an additional mechanism of contaminant removal. The methods of land application currently in use or considered for use in East County are spray irrigation and infiltration/percolation.

The area of land required for purposes of land disposal is generally proportional to the wastewater flow volume. This is influenced, however, by soil type and climatic conditions. Given the dry, hot weather conditions common to East County, soil characteristics become the factor that dictates the suitability of a particular area for land disposal and influences the selection of the appropriate land disposal option.

Spray irrigation systems are generally employed with soils characterized as having a lower range of infiltration rates. Therefore, a relatively large area of land is required for the disposal of wastewater using spray irrigation methods. Conversely, infiltration/percolation land disposal systems are restricted to areas with highly permeable soils such as sands or sandy loams. Using infiltration/percolation systems, one can achieve the disposal of large wastewater flows with relatively small land areas.

Rate of infiltration considerations must be balanced with groundwater quality protection. Following percolation through the soil matrix, infiltrated wastewater may enter groundwater supplies

and adversely impact groundwater quality. Several East County service entities contemplating land treatment are located in areas of close proximity to waters of the Delta. High water table elevations in these areas may limit the use of land application as a disposal option because of the greater potential for adversely impacting groundwater quality. Additionally, and as noted in the General Plan, several regions in East County have been identified by the County Department of Health as unsuitable for septic tank use as a result of elevated nitrate groundwater concentrations. These areas may be considered unsuitable for land disposal through spray irrigation or infiltration/percolation.

One of the most important consideration with respect to land disposal of treated wastewater is the cost of land. Over the past three years, land costs have risen from a range of $3,000 - $5,000 per acre to approximately $20,000 to $25,000 per acre. Even if a land disposal project is considered to be technically feasible, the recent significant increase in property costs have made land disposal a less viable alternative. Expansion of a land disposal system may be a consideration for an existing service entity. However, development of new land treatment systems designed to handle significant flow volumes associated with projected growth in areas of East County may not be the most cost effective approach given the increasing land costs.

Table 1 presents a summary of land disposal sizing criteria and the cost estimates for developing a land disposal system. The disposal area sizing criteria are based on existing operations of East County sewer service entities and information contained in the literature. Disposal cost estimates assume a cost for land of $25,000 per acre.

Surface Water Discharge

An alternative means of wastewater disposal is surface water discharge. The closest area suitable for discharge of East County wastewater effluent is the Delta. An agency proposing discharge would be required to obtain a permit which involves an evaluation directed by the RWQCB. A proposed project would be evaluated in light of existing Delta water uses. Currently, Delta Diablo Sanitation District, Central Contra Costa Sanitation District, the City of Sacramento, Discovery Bay and others discharge treated wastewater into the Delta. During periods of low salinity levels, the City of Antioch uses this water as a drinking water source. The Contra Costa County Water District exports water used for drinking from Rock Slough. The State Water Project exports water to Southern California from Clifton Court Forbay. Existing uses, coupled with the sensitivity of the wetlands environment in this area, have contributed to some restraint by the RWQCB with regard to issuing new surface water discharge permits. Discussions with

Table 1 Summary of Land Disposal Sizing and Cost Estimates

	Spray irrigation	Infiltration/percolation
Land area required per mgd of wastewater (acres)	260[a]	22[a]
Range (acres)	140 - 560[b]	2 - 62[b]
Depth to groundwater (feet)	Approximately 10[b]	Approximately 15[b]
Cost per mgd (x $1 million)	6.75[a]	0.55[a]

[a]Based on information supplied by Dewante and Stowell.
[b]Clark J. W., W. Viessman, and M. J. Hammer, "Water Supply and Pollution Control," Third Edition, 1977.

representatives of the RWQCB, Central Valley Region, indicate that if technically feasible, land disposal is the preferred alternative for disposal of wastewater in East County.

SEWER SERVICE ENTITY SUMMARY

This section summarizes the situation with respect to growth in the sewer service entities in East County. The discussion focuses on those regions in East County that are projected as part of the General Plan Review to undergo significant growth. Included in this discussion are the Oakley-Bethel Island Wastewater Management Authority, the City of Brentwood, the Veale Tract area, and the community of Discovery Bay.

Oakley-Bethel Island Wastewater Management Authority

Currently, the Oakley-Bethel Island Wastewater Management Authority disposes of approximately 65 percent of its treated effluent utilizing a flood irrigation system. There are high return flows from this irrigation. High return flows indicate that the maximum wastewater loading has been achieved. Approximately 25 percent of the total annual effluent is used by local agriculture for the leaching of their peat fields. This water is taken almost exclusively during the winter with very small flows being used for the irrigation of crops during other parts of the year. The remaining 10 percent of the water is disposed of through the use of evaporation/percolation ditches.

The Oakley Bethel Island Wastewater Management Authority has considered combining surface water discharge and land disposal options as a part of their facility expansion plans. The significant increase in land prices since 1985 has forced the service entity to reconsider whether spray irrigation is a cost-effective treated wastewater disposal option. The Oakley Bethel Island Wastewater Management Authority has initiated an informal investigation into the possibility of acquiring a surface water discharge permit.

A surface water discharge into the center of big break was recommended for Oakley by Dewante and Stowell. This outfall would be approximately 7 miles upstream from the City of Antioch's intake for their drinking water supply. Studies conducted by Oakley are needed to ensure that a 10:1 dillution is achieved at the point of discharge.

Since Oakley-Bethel Island will likely have difficulty obtaining a discharge permit, we have assumed that they will continue to use land disposal and pay the higher land cost.

Brentwood

In order to meet the sewer service needs of the projected population, the City of Brentwood has begun construction on the first stage of a two-stage treatment plant upgrade. Under these plans, plant capacity will increase from the existing 0.6 million gallons per day (mgd) to 1.8 mgd in the first stage and to 2.7 mgd in the second stage. If growth is more rapid than currently projected, the plant capacity expansion for the second stage of the treatment plant upgrade may be increased to 5.4 mgd.

Currently, wastewater effluent disposal is carried out utilizing infiltration/percolation ponds. The percolation ponds are situated on a type of soil called Delhi Sand with characteristic infiltration rates in the range of 12 to 40 feet of water per day. Currently Brentwood is disposing of 100,000 gal/acre/day. Beneath the ponds is a natural clay layer which acts as a collection system for the percolating water. The treatment plant is surrounded by a french drain system designed to collect water that is caught by this clay layer and transport it to Marsh Creek. The proposed capacity increases would proportional increase the discharge flows to Marsh Creek.

Brentwood's permit for land disposal is currently being appealed by the Green Belt Alliance. The group is made up of property owners, and is supported by local environmental concerns. The Green Belt Alliance states that Brentwood's land disposal method may effect potable water supplies. With respect to nitrate levels, monitoring data indicate that groundwater quality has shown improvement as a result of infiltration of the treatment plant wastewater effluent. The appeal is currently under review by the RWQCB.

Dewante and Stowell, the City of Brentwood's engineer, stated that Marsh Creek is considered to be a nonpotable water source. Water quality testing performed on the water upstream and downstream of the discharge point show that downstream water is at a higher quality than the upstream water. These findings indicate that the higher quality effluent water may be contributing to an improvement in water quality in Marsh Creek. We have assumed that the City of Brentwood will be allowed to continue to use land disposal in the future.

Veale Tract Area

The Veale Tract area is anticipated to have a significant population growth as part of the Spread alternative growth scenario. The soil maps in the area indicate large areas of Delhi Sand. This is the same soil type underlying the Brentwood wastewater treatment facility. This soil type indicates that land disposal through the use of infiltration/percolation ponds is a

feasible disposal alternative. Additional considerations are that the land elevation in this area is lower than in the Brentwood area so groundwater levels may be higher and infiltration rates less than what is found at Brentwood. For the purposes of the project, per capita costs for treatment and disposal in the Veale Tract are estimated to be similar to the cost associated with the City of Brentwood system.

Discovery Bay

In response to past difficulties in complying with state discharge requirements, the treatment system at Discovery Bay has recently been upgraded. The current means of effluent disposal is surface water discharge into Indian Slough. Current treatment plant capacity is at 0.8 mgd with a planned treatment plant expansion to 1.2 mgd. The 1.2 mgd capacity is adequate in meeting the projected service demands associated with the growth in that area. Although the discharge is into an environmentally sensitive area, we have assumed that the RWQCB will allow Discovery Bay to continue with their present disposal scheme.

COST ESTIMATES

This section summarizes the costs associated with each of the five alternative growth scenarios to meet projected water and wastewater needs in the County. The cost estimates have been modified relative to the revised January 1989 cost estimates. Oakley-Bethel Island Wastewater Management Authority and the City of Brentwood's wastewater disposal cost have been updated to reflect land disposal of treated wastewater effluent. Tables 2 and 4 present a summary of the population projections for the five alternative growth scenarios and the estimated cost for water and wastewater service, respectively. Tables 3 and 5 summarize the differences in projected populations between the Composite and Spread alternatives as defined in the revised January 1989 report prepared by Brown and Caldwell and the Composite and Spread alternatives as defined in the updated General Plan.

Because land disposal is technically feasible for Brentwood and Brentwood is well along the way in implementing such a program with capacity for future growth a regional outfall system discharging into the San Joaquin river is unlikely to be implemented. Oakley-Bethel Island, on the other hand, may choose to implement a river disposal option on its own but for the purposes of this report we have assumed that they would continue with land disposal. Consequently, there have been significant changes in wastewater treatment and disposal costs between this report and the revised

Table 2. Projected Water Service Populations and Cost Estimates for the Alternative Growth Scenarios

Service Entity	Traffic Zone Analysis Population Estimates		Cost in Dollars	
	Alternative	Population	Transpost	Treatment
East Bay Municipal Utility District	1985	374,894		
	Project	442,606	68,999,000	15,100,000
	Composite	443,898	70,315,000	15,388,000
	Spread	500,714	141,191,000	50,963,000
	Transfer	481,294	116,473,000	37,935,000
	UI	456,428	84,824,000	21,254,000
Contra Costa Water District	1985	176,982		
	Project	192,719	7,023,000	0
	Composite	190,166	5,850,000	0
	Spread	191,070	6,265,000	0
	Transfer	192,719	6,899,000	0
	UI	195,192	8,159,000	0
Antioch	1985	49,708		
	Project	92,524	27,445,000	8,610,000
	Composite	90,865	26,382,000	8,283,000
	Spread	102,542	33,867,000	10,589,000
	Transfer	92,524	27,445,000	8,610,000
	UI	92,524	27,445,000	8,610,000
Martinez	1985	27,481		
	Project	34,736	7,864,000	1,909,000
	Composite	34,736	7,864,000	1,909,000
	Spread	34,736	7,864,000	1,909,000
	Transfer	34,736	7,864,000	2,057,000
	UI	35,299	8,475,000	1,909,000
Pittsburg/West Pittsburg	1985	52,130		
	Project	69,193	11,290,000	4,152,000
	Composite	68,044	10,251,000	4,083,000
	Spread	76,747	19,869,000	4,605,000
	Transfer	69,193	11,290,000	4,152,000
	UI	72,340	14,864,000	4,340,000
Oakley Water District	1985	9,081		
	Project	30,703	4,476,000	19,330,000
	Composite	30,703	4,476,000	19,330,000
	Spread	30,703	4,476,000	19,330,000
	Transfer	28,103	3,938,000	17,006,000
	UI	28,103	3,938,000	17,006,000
Brentwood	1985	7,804		
	Project	47,928	30,414,000	5,509,000
	Composite	44,022	27,453,000	5,003,000
	Spread	48,564	30,896,000	5,591,000
	Transfer	30,417	17,141,000	3,124,000
	UI	30,417	17,141,000	3,124,000
Byron	1985	704		
	Project	644	0	0
	Composite	644	0	0
	Spread	644	0	0
	Transfer	644	0	0
	UI	644	0	0
Discovery Bay	1985	2,942		
	Project	8,148	1,378,000	285,000
	Composite	8,148	1,378,000	285,000
	Spread	8,148	1,378,000	285,000
	Transfer	8,148	1,378,000	285,000
	UI	8,148	1,378,000	285,000

Table 2. Projected Water Service Populations and Cost Estimates for the Alternative Growth Scenarios

Service Entity	Traffic Zone Analysis Population Estimates		Cost, dollars	
	Alternative	Population	Transpost	Treatment
Bethel Island Area	1985	2,714		
	Project	7,698	3,688,000	689,000
	Composite	7,698	3,688,000	656,000
	Spread	16,612	10,285,000	1,958,000
	Transfer	4,813	1,546,000	292,000
	UI	4,803	1,546,000	292,000
Veale Tract Area	1985	631		
	Project	623	0	0
	Composite	623	0	0
	Spread	15,053	11,150,000	2,109,000
	Transfer	623	0	0
	UI	623	0	0
Unallocated Population	1985	4,018		
	Project	2,528	0	0
	Composite	2,528	0	0
	Spread	2,528	0	0
	Transfer	2,528	0	0
	UI	2,528	0	0
Totals	1985	709,089		
	Project	930,050	162,577,000	55,584,000
	Composite	922,075	157,657,000	54,937,000
	Spread	1,028,061	267,241,000	97,339,000
	Transfer	945,742	193,974,000	73,461,000
	UI	927,049	167,770,000	56,820,000

Table 3. Comparison of the Old and New Composite and Spread Alternatives for Water

Districts		Populations		Cost, dollars Transport		Treatment	
		Composite	Spread	Composite	Spread	Composite	Spread
EBMUD	Old	449,570	504,724	76,095,000	146,295,000	16,653,000	53,653,000
	New	443,898	500,714	70,315,000	141,191,000	15,388,000	50,963,000
	Difference	-5,672	-4,010	-5,780,000	-5,104,000	-1,265,000	-2,690,000
CCWD	Old	190,122	190,947	5,830,000	6,209,000	0	0
	New	190,166	191,070	5,850,000	6,265,000	0	0
	Difference	44	123	20,000	56,000	0	0
Antioch	Old	86,396	100,571	23,517,000	32,602,000	7,400,000	10,200,000
	New	90,865	102,542	26,382,000	33,867,000	8,283,000	10,589,000
	Difference	4,469	1,971	2,865,000	1,265,000	883,000	389,000
Martinez	Old	33,998	33,998	7,069,000	7,069,000	1,715,000	1,715,000
	New	34,736	34,736	7,864,000	7,864,000	1,909,000	1,909,000
	Difference	738	738	795,000	795,000	194,000	194,000
Pittsburg	Old	68,585	74,837	10,600,000	17,700,000	4,100,000	4,500,000
	New	68,044	76,747	10,251,000	19,869,000	4,083,000	4,605,000
	Difference	-541	1,910	-349,000	2,169,000	-17,000	105,000
Oakley	Old	29,843	29,843	4,291,000	4,291,000	18,557,000	18,557,000
	New	30,703	30,703	4,476,000	4,476,000	19,330,000	19,330,000
	Difference	860	860	185,000	185,000	773,000	773,000
Brentwood	Old	44,768	48,684	28,031,000	30,031,000	5,106,000	5,606,000
	New	44,022	48,564	27,453,000	30,896,000	5,003,000	5,591,000
	Difference	-746	-120	-578,000	865,000	-103,000	-15,000
Byron	Old	632	632	0	0	0	0
	New	644	644	0	0	0	0
	Difference	12	12	0	0	0	0
Discovery Bay	Old	8,148	8,148	1,378,000	1,378,000	285,000	285,000
	New	8,148	8,148	1,378,000	1,378,000	285,000	285,000
	Difference	0	0	0	0	0	0
Bethel Island	Old	8,636	18,705	4,382,000	11,833,000	1,589,000	2,999,000
	New	7,698	16,612	3,688,000	10,285,000	656,000	1,958,000
	Difference	-938	-2,093	-694,000	-1,548,000	-933,000	-1,041,000
Veale Tract Area	Old	607	14,738	0	0	10,906,000	2,063,000
	New	623	15,053	0	11,150,000	0	2,109,000
	Difference	16	315	0	11,150,000	-10,906,000	46,000
Other	Old	2,719	2,493	0	0	0	0
	New	2,528	2,528	0	0	0	0
	Difference	-191	35	0	0	0	0
Total	Old	924,024	1,028,320	161,193,000	257,408,000	66,311,000	99,578,000
	New	922,075	1,028,061	157,657,000	267,241,000	54,937,000	97,339,000
	Difference	-1,949	-259	-3,536,000	9,833,000	-11,374,000	-2,239,000

Table 4. Projected WProjected Water Service Populations and Cost Estimates fEstimates for the Alternative Growth Scenarios

Sewer Service Entity	Traffic Zone Analysis Population Estimates		Cost, dollars	
	Alternative	Population	Transport	Treatment
Central Contra Costa Sanitary District	1,985	352,354		
	Project	413,637	73,910,000	24,942,000
	Composite	407,796	73,910,000	22,565,000
	Spread	469,712	73,910,000	47,765,000
	Transfer	452,325	73,910,000	40,688,000
	UI	418,579	73,910,000	26,954,000
Delta Diablo Sanitation District	1,985	100,769		
	Project	165,407	7,029,000	9,288,000
	Composite	162,407	9,534,000	6,684,000
	Spread	178,415	14,984,000	8,444,000
	Transfer	165,407	7,029,000	9,288,000
	UI	166,981	7,201,000	8,827,000
Stege Sanitary District	1,985	36,651		
	Project	33,593	0	0
	Composite	33,593	0	0
	Spread	33,593	0	0
	Transfer	33,593	0	0
	UI	33,593	0	0
West Contra Costa Sanitary District	1,985	67,747		
	Project	75,407	930,000	0
	Composite	77,664	1,204,000	0
	Spread	77,664	1,204,000	0
	Transfer	75,407	930,000	0
	UI	80,925	1,600,000	0
Mountain View Sanitary District	1,985	15,834		
	Project	20,428	6,875,000	3,589,000
	Composite	20,217	6,559,000	3,425,000
	Spread	20,217	6,559,000	3,425,000
	Transfer	20,428	6,875,000	3,589,000
	UI	20,428	6,875,000	3,589,000
Dublin-San Ramon Services	1,985	12,453		
	Project	18,018	2,666,000	2,804,000
	Composite	18,018	2,666,000	2,804,000
	Spread	18,018	2,666,000	2,804,000
	Transfer	18,018	2,666,000	2,804,000
	UI	18,018	2,666,000	2,804,000
Rodeo Sanitary District	1,985	8,189		
	Project	7,424	0	0
	Composite	7,424	0	0
	Spread	7,424	0	0
	Transfer	7,424	0	0
	UI	7,424	0	0
Crockett-Valona Sanitary District	1,985	3,019		
	Project	2,798	0	0
	Composite	2,798	0	0
	Spread	2,798	0	0
	Transfer	2,798	0	0
	UI	2,798	0	0
Oakley-Bethel Island Wastewater Management Authority	1,985	9,605		
	Project	38,256	8,596,000	30,522,000
	Composite	38,256	8,596,000	30,522,000
	Spread	47,170	11,271,000	40,018,000
	Transfer	32,671	6,920,000	24,572,000
	UI	32,671	6,920,000	24,572,000
Byron Sanitary District	1,985	704		
	Project	644	0	0
	Composite	644	0	0
	Spread	644	0	0
	Transfer	644	0	0
	UI	644	0	0

Table 4. Projected WProjected Water Service Populations and Cost
Estimates fEstimates for the Alternative Growth Scenarios

Sewer Service Entity	Traffic Zone Analysis Population Estimates		Cost, dollars	
	Alternative	Population	Transport	Treatment
City of Richmond	1,985	52,857		
	Project	54,281	0	0
	Composite	54,473	0	0
	Spread	54,473	0	0
	Transfer	54,281	0	0
	UI	56,873	0	0
City of Hecules City of Pinole	1,985	23,594		
	Project	38,036	1,871,000	0
	Composite	40,746	2,222,000	0
	Spread	40,746	2,222,000	0
	Transfer	38,036	1,871,000	0
	UI	43,416	2,568,000	0
Discovery Bay	1,985	2,942		
	Project	8,148	1,562,000	1,600,000
	Composite	8,148	1,562,000	1,600,000
	Spread	8,148	1,562,000	1,600,000
	Transfer	8,148	1,562,000	1,600,000
	UI	8,148	1,562,000	1,600,000
Port Costa	1,985	193		
	Project	190	0	0
	Composite	190	0	0
	Spread	190	0	0
	Transfer	190	0	0
	UI	190	0	0
City of Brentwood	1,985	7,805		
	Project	47,811	12,004,000	8,402,000
	Composite	43,905	10,832,000	7,230,000
	Spread	48,447	12,195,000	8,593,000
	Transfer	30,379	6,774,000	3,173,000
	UI	30,379	6,774,000	3,173,000
Veale Tract Area	1,985	631		
	Project	623	0	0
	Composite	623	0	0
	Spread	15,053	4,516,000	4,515,000
	Transfer	623	0	0
	UI	623	0	0
Unallocated Populations	1,985	13,742		
	Project	5,350	0	0
	Composite	5,350	0	0
	Spread	5,350	0	0
	Transfer	5,350	0	0
	UI	5,350	0	0
Totals	1,985	706,031		
	Project	930,051	115,443,000	81,147,000
	Composite	922,252	117,085,000	74,830,000
	Spread	1,028,062	131,089,000	117,164,000
	Transfer	945,722	108,537,000	85,714,000
	UI	893,447	110,076,000	71,519,000

Table 5. Comparison of the Old and New Composite and Spread Alrternatives for Wastewater

Districts		Populations		Cost, dollars			
				Transport		Treatment and Disposal	
		Composite	Spread	Composite	Spread	Composite	Spread
Central Contra Costa Sanitary District	Old	408,371	467,158	73,910,000	77,736,000	22,799,000	46,725,000
	New	407,796	469,712	73,910,000	73,910,000	22,565,000	47,765,000
	Difference	-575	2,554	0	-3,826,000	-234,000	1,040,000
Delta Diablo Sanitation District	Old	157,823	175,272	8,044,000	13,917,000	6,202,000	7,076,000
	New	162,231	178,415	9,534,000	14,984,000	6,684,000	8,444,000
	Difference	4,408	3,143	1,490,000	1,067,000	482,000	1,368,000
Stege Sanitary District	Old	32,656	32,656	0	0	0	0
	New	33,593	33,593	0	0	0	0
	Difference	937	937	0	0	0	0
West Contra Costa Sanitary District	Old	77,161	77,161	1,143,000	1,143,000	0	0
	New	77,664	77,664	1,204,000	1,204,000	0	0
	Difference	503	503	61,000	61,000	0	0
Mountain View Sanitary District	Old	19,887	19,881	6,056,000	6,056,000	3,162,000	3,162,000
	New	20,217	20,217	6,559,000	6,559,000	3,425,000	3,425,000
	Difference	330	336	503,000	503,000	263,000	263,000
Dublin-San Ramon Services	Old	17,927	17,927	2,622,000	2,622,000	2,758,000	2,758,000
	New	18,018	18,018	2,666,000	2,666,000	2,804,000	2,804,000
	Difference	91	91	44,000	44,000	46,000	46,000
Rodeo Sanitary District	Old	7,387	7,387	0	0	0	0
	New	7,424	7,424	0	0	0	0
	Difference	37	37	0	0	0	0
Crockett-Valona Sanitary District	Old	3,065	3,065	0	0	0	0
	New	2,798	2,798	0	0	0	0
	Difference	-267	-267	0	0	0	0
Oakley-Bethel Island Wastewater Management Authority	Old	38,228	48,297	8,587,000	11,608,000	23,733,000	31,173,000
	New	37,010	45,924	8,596,000	11,271,000	30,522,000	40,018,000
	Difference	-1,218	-2,373	9,000	-337,000	6,789,000	8,845,000
Byron Sanitary District	Old	632	632	0	0	0	0
	New	1,890	1,890	0	0	0	0
	Difference	1,258	1,258	0	0	0	0
City of Richmond	Old	53,824	53,824	0	0	0	0
	New	54,473	54,473	0	0	0	0
	Difference	649	649	0	0	0	0
City of Hecules City of Pinole	Old	41,743	41,743	2,351,000	2,351,000	0	0
	New	40,746	40,746	2,222,000	2,222,000	0	0
	Difference	-997	-997	-129,000	-129,000	0	0
Discovery Bay	Old	44,768	48,684	11,089,000	12,264,000	29,411,000	32,305,000
	New	43,905	48,447	10,832,000	12,195,000	7,230,000	8,593,000
	Difference	-863	-237	-257,000	-69,000	-22,181,000	-23,712,000
Port Costa	Old	8,148	8,148	1,562,000	1,562,000	1,600,000	1,600,000
	New	8,148	8,148	1,562,000	1,562,000	1,600,000	1,600,000
	Difference	0	0	0	0	0	0
City of Brentwood	Old	208	208	0	0	0	0
	New	190	190	0	0	0	0
	Difference	-18	-18	0	0	0	0
Veale Tract Area	Old	607	14,738	0	4,421,000	0	6,927,000
	New	623	15,053	0	4,516,000	0	4,515,000
	Difference	16	315	0	95,000	0	-2,412,000
Unallocated Populations	Old	11,595	11,539	0	0	0	0
	New	5,350	5,350	0	0	0	0
	Difference	-6,245	-6,189	0	0	0	0
Totals -	Old	924,030	1,028,320	115,364,000	133,680,000	89,665,000	131,726,000
	New	922,075	1,028,061	117,085,000	131,089,000	74,830,000	117,164,000
	Difference	-1,955	-259	1,721,000	-2,591,000	-14,835,000	-14,562,000

January 1989 report for Oakley-Bethel Island, Brentwood, and the Veale Tract area. The 30 percent increase in cost for Oakley-Bethel Island is a reflection of the increase in the cost of land in East County. The 75 percent decrease in estimated cost associated with future needs for the City of Brentwood is a result of a recent plant capacity increase that has been funded. The Veale Tract area has a 33 percent decrease in cost for wastewater service. This decrease is based on the use of percolation ponds for land disposal of treated wastewater rather than spray irrigation methods assumed to be the means of disposal in the revised January 1989 report.

BROWN AND CALDWELL
CONSULTING ENGINEERS

CONTRA COSTA

89 OCT 24 PM 2:27

COMMUNITY DEVELOPMENT DEPT

October 23, 1989

Mr. Douglas Duncan
Duncan and Jones
2161 Shattuck Avenue
Berkeley, California 94704

11-3182-01/7

Subject: Contra Costa General Plan Update
Additional Alternative Evaluation Corrections

Dear Mr. Duncan:

As requested by Mr. Dennis Barry, we have corrected the inconsistency in populations between Tables 2 and 4 in our September 25, 1989, submittal of our report, "Alternative Evaluation for Water, Sewer, and Storm Drainage Infrastructure Requirements in Contra Costa County." The inconsistency was due to addition errors. These errors have been corrected to within 0.02% and the corrected tables are enclosed. We are sorry for the inconvenience. Please insert the new tables in your report. We have sent a copy to Mr. Barry. If you have any questions, please call me.

Very truly yours,

BROWN AND CALDWELL

William J. Miller, Jr.

William J. Miller, Jr.
Project Engineer

WJM:ljk
Enclosures

cc: Mr. Dennis Barry, Contra Costa County
Mr. William O. Maddaus, Brown and Caldwell
Mr. Denis O'Malley, Brown and Caldwell
Mr. John Nyznyk, Brown and Caldwell

Table 2. Projected Water Service Populations and Cost Estimates for the Alternative Growth Scenarios

Service Entity	Traffic Zone Analysis Population Estimates		Cost in Dollars	
	Alternative	Population	Transpost	Treatment
East Bay Municipal Utility District	1985	374,894	-	
	Project	442,606	68,959,000	15,100,000
	Composite	443,898	70,315,000	15,388,000
	Spread	500,714	141,191,000	50,963,000
	Transfer	481,294	116,473,000	37,935,000
	UI	456,428	84,824,000	21,254,000
Contra Costa Water District	1985	176,982		
	Project	192,719	7,023,000	0
	Composite	190,166	5,850,000	0
	Spread	191,070	6,265,000	0
	Transfer	192,719	6,899,000	0
	UI	195,192	8,159,000	0
Antioch	1985	49,708		
	Project	92,524	27,445,000	8,610,000
	Composite	90,865	26,382,000	8,283,000
	Spread	102,542	33,867,000	10,589,000
	Transfer	92,524	27,445,000	8,610,000
	UI	92,524	27,445,000	8,610,000
Martinez	1985	27,481		
	Project	34,736	7,864,000	1,909,000
	Composite	34,736	7,864,000	1,909,000
	Spread	34,736	7,864,000	1,909,000
	Transfer	34,736	7,864,000	2,057,000
	UI	35,299	8,475,000	1,909,000
Pittsburg/West Pittsburg	1985	52,130		
	Project	69,193	11,290,000	4,152,000
	Composite	68,044	10,251,000	4,083,000
	Spread	76,747	19,869,000	4,605,000
	Transfer	69,193	11,290,000	4,152,000
	UI	72,340	14,864,000	4,340,000
Oakley Water District	1985	9,081		
	Project	30,703	4,476,000	19,330,000
	Composite	30,703	4,476,000	19,330,000
	Spread	30,703	4,476,000	19,330,000
	Transfer	28,103	3,938,000	17,006,000
	UI	28,103	3,938,000	17,006,000
Brentwood	1985	7,804		
	Project	47,928	30,414,000	5,509,000
	Composite	44,022	27,453,000	5,003,000
	Spread	48,564	30,896,000	5,591,000
	Transfer	30,417	17,141,000	3,124,000
	UI	30,417	17,141,000	3,124,000
Byron	1985	704		
	Project	644	0	0
	Composite	644	0	0
	Spread	644	0	0
	Transfer	644	0	0
	UI	644	0	0
Discovery Bay	1985	2,942		
	Project	8,148	1,378,000	285,000
	Composite	8,148	1,378,000	285,000
	Spread	8,148	1,378,000	285,000
	Transfer	8,148	1,378,000	285,000
	UI	8,148	1,378,000	285,000

Table 2. Projected Water Service Populations and Cost Estimates for the Alternative Growth Scenarios

Service Entity	Traffic Zone Analysis Population Estimates		Cost, dollars	
	Alternative	Population	Transport	Treatment
Bethel Island Area	1985	2,714		
	Project	7,698	3,688,000	689,000
	Composite	7,698	3,688,000	656,000
	Spread	16,612	10,285,000	1,958,000
	Transfer	4,813	1,546,000	292,000
	UI	4,803	1,546,000	292,000
Veale Tract Area	1985	631		
	Project	623	0	0
	Composite	623	0	0
	Spread	15,053	11,150,000	2,109,000
	Transfer	623	0	0
	UI	623	0	0
Unallocated Population	1985	4,018		
	Project	2,528	0	0
	Composite	2,528	0	0
	Spread	2,528	0	0
	Transfer	2,528	0	0
	UI	2,528	0	0
Totals	1985	709,089		
	Project	930,050	162,577,000	55,584,000
	Composite	922,075	157,657,000	54,937,000
	Spread	1,028,061	267,241,000	97,339,000
	Transfer	945,742	193,974,000	73,461,000
	UI	927,049	167,770,000	56,820,000

Table 4. Projected WProjected Water Service Populations and Cost Estimates fEstimates for the Alternative Growth Scenarios

Sewer Service Entity	Traffic Zone Analysis Population Estimates		Cost, dollars	
	Alternative	Population	Transport	Treatment
Central Contra Costa Sanitary District	1,985	352,354		
	Project	413,637	73,910,000	24,942,000
	Composite	407,796	73,910,000	22,565,000
	Spread	469,712	73,910,000	47,765,000
	Transfer	452,325	73,910,000	40,688,000
	UI	418,579	73,910,000	26,954,000
Delta Diablo Sanitation District	1,985	100,769		
	Project	165,407	7,029,000	9,288,000
	Composite	162,407	9,534,000	6,684,000
	Spread	178,415	14,984,000	8,444,000
	Transfer	165,407	7,029,000	9,288,000
	UI	166,981	7,201,000	8,827,000
Stege Sanitary District	1,985	36,651		
	Project	33,593	0	0
	Composite	33,593	0	0
	Spread	33,593	0	0
	Transfer	33,593	0	0
	UI	33,593	0	0
West Contra Costa Sanitary District	1,985	67,747		
	Project	75,407	930,000	0
	Composite	77,664	1,204,000	0
	Spread	77,664	1,204,000	0
	Transfer	75,407	930,000	0
	UI	80,925	1,600,000	0
Mountain View Sanitary District	1,985	15,834		
	Project	20,428	6,875,000	3,589,000
	Composite	20,217	6,559,000	3,425,000
	Spread	20,217	6,559,000	3,425,000
	Transfer	20,428	6,875,000	3,589,000
	UI	20,428	6,875,000	3,589,000
Dublin-San Ramon Services	1,985	12,453		
	Project	18,018	2,666,000	2,804,000
	Composite	18,018	2,666,000	2,804,000
	Spread	18,018	2,666,000	2,804,000
	Transfer	18,018	2,666,000	2,804,000
	UI	18,018	2,666,000	2,804,000
Rodeo Sanitary District	1,985	8,189		
	Project	7,424	0	0
	Composite	7,424	0	0
	Spread	7,424	0	0
	Transfer	7,424	0	0
	UI	7,424	0	0
Crockett-Valona Sanitary District	1,985	3,019		
	Project	2,798	0	0
	Composite	2,798	0	0
	Spread	2,798	0	0
	Transfer	2,798	0	0
	UI	2,798	0	0
Oakley-Bethel Island Wastewater Management Authority	1,985	9,605		
	Project	38,256	8,596,000	30,522,000
	Composite	38,256	8,596,000	30,522,000
	Spread	47,170	11,271,000	40,018,000
	Transfer	32,671	6,920,000	24,572,000
	UI	32,671	6,920,000	24,572,000
Byron Sanitary District	1,985	704		
	Project	644	0	0
	Composite	644	0	0
	Spread	644	0	0
	Transfer	644	0	0
	UI	644	0	0

Table 4. Projected WProjected Water Service Populations and Cost Estimates fEstimates for the Alternative Growth Scenarios

Sewer Service Entity	Traffic Zone Analysis Population Estimates		Cost, dollars	
	Alternative	Population	Transport	Treatment
City of Richmond	1,985	52,857		
	Project	54,281	0	0
	Composite	54,473	0-	0
	Spread	54,473	0	0
	Transfer	54,281	0	0
	UI	56,873	0	0
City of Hecules City of Pinole	1,985	23,594		
	Project	38,036	1,871,000	0
	Composite	40,746	2,222,000	0
	Spread	40,746	2,222,000	0
	Transfer	38,036	1,871,000	0
	UI	43,416	2,568,000	0
Discovery Bay	1,985	2,942		
	Project	8,148	1,562,000	1,600,000
	Composite	8,148	1,562,000	1,600,000
	Spread	8,148	1,562,000	1,600,000
	Transfer	8,148	1,562,000	1,600,000
	UI	8,148	1,562,000	1,600,000
Port Costa	1,985	193		
	Project	190	0	0
	Composite	190	0	0
	Spread	190	0	0
	Transfer	190	0	0
	UI	190	0	0
City of Brentwood	1,985	7,805		
	Project	47,811	12,004,000	8,402,000
	Composite	43,905	10,832,000	7,230,000
	Spread	48,447	12,195,000	8,593,000
	Transfer	30,379	6,774,000	3,173,000
	UI	30,379	6,774,000	3,173,000
Veale Tract Area	1,985	631		
	Project	623	0	0
	Composite	623	0	0
	Spread	15,053	4,516,000	4,515,000
	Transfer	623	0	0
	UI	623	0	0
Unallocated Populations	1,985	13,742		
	Project	5,350	0	0
	Composite	5,350	0	0
	Spread	5,350	0	0
	Transfer	5,350	0	0
	UI	5,350	0	0
Totals	1,985	709,089		
	Project	930,051	115,443,000	81,147,000
	Composite	922,252	117,085,000	74,830,000
	Spread	1,028,062	131,089,000	117,164,000
	Transfer	945,722	108,537,000	85,714,000
	UI	927,040	110,076,000	71,519,000

APPENDIX G

RECOMMENDATION REGARDING AGRICULTURAL PRESERVATION PROGRAMS

CALIFORNIA FARMLAND PDR PROGRAMS

Marin County--Marin County has probably the most advanced farmland PDR program in the state. Marin has used a combination of public and private funds to purchase conservation easements on over 12,000 acres of ranchland in West Marin County. The Marin Agricultural Land Trust has done most of the work. Funding sources include $1 million from the State Coastal Conservancy, $1 million from the San Francisco Foundation, $200,000 from the County Open Space District, and $15 million from Proposition 70. Two projects on over 2000 acres have recently been approved by the county using Proposition 70 funds.

Monterey--Monterey County recently completed development of a countywide farmland PDR program. The County is now in the process of working with a local land trust to implement the program. The County has received $1 million from the State Coastal Conservancy and $4 million from Proposition 70. The County anticipates closing its first transaction later this year. (See citation)

Riverside--The City of Riverside received $10 million from Proposition 70 for a historic Citrus Park. Plans are under way to acquire both fee title an conservation easements on the properties targeted for protection.

Sacramento--The County has recently completed a report on the condition of open space resources in the County. The report's recommendations rely heavily upon purchasing development rights on farmland. (See citation)

San Bernardino--The county received $20 million from Proposition 70 for buying development rights in the Chino Agricultural Preserve. Since passage of Prop 70, a local land trust has been established and will probably take over development and administration of the program. The County has negotiated an advance of the money from the State to begin working on the program.

San Mateo--This county will receive up to $8 million from Prop 70. One of the main farmland transactions is moving forward in an area south of Half Moon Bay where the land was purchase in fee, Prop 70 funds will be used to pay for the development rights, and the restricted fee title will be sold to a farmer.

Santa Cruz--Santa Cruz received $1 million from Proposition 70 and has developed a draft plan to administer and implement a farmland PDR program. A local land trust is also very active in farmland conservation activities.

Santa Barbara--This county also received $1 million for buying development rights on farmland. The County is in the process of developing a program and priority areas for acquisition.

Solano--Here, a local land trust is actively involved in farmland conservation activities in the Suisun Valley, with the help of funds from a Mello-Roos district, a recent grant from the state Department of Parks and Recreation and the State Coastal Conservancy.

Sonoma--Sonoma County's program is among the most effective in the state. The county's recently-adopted agricultural element has strong language for implementing a farmland PDR program. The County and the local land trust have received a wide variety of funds to carry out its land conservation program: State Coastal Conservancy, Fish and Game, Wildlife Conservation Board, and Proposition 70. The City of Petaluma is also developing a Transfer of Development Rights Program.

The first PDR program was initiated in 1974 in Suffolk County, New York. Since then, numerous states, counties, and towns have instituted similar programs. Collectively, these initiatives have successfully protected tens of thousands of acres of prime and important farmland.

<u>How PDR Works</u>

Although there are variations in the way individual PDR programs are implemented, there are a number of common denominators.

The process is generally initiated by the landowner through an application procedure. A farm's eligibility for participation in a program is based on a set of pre-established criteria. The criteria most often considered are: quality of the soil resource; viability of agriculture in the area in which the farm is located; quality of management of the farm and its economic viability; and the degree of threat to its continued use for farming. In some cases, areas of special concern are targeted for development right acquisitions (i.e., agricultural districts, groundwater recharge areas).

When a state or local government purchases a deed restriction on a parcel of land, it has limited its future use to agricultural activities, thus removing the parcel's development value. Consequently, the price paid by the program to the farmer for the restriction is determined by subtracting the agricultural value of the land from its full fair-market value, based on current market appraisals. In the case of those programs that purchase restrictions for a period of time, the value of the restriction is, generally, some percentage of the full development value. Note: Sidebar with simple example.

The various PDR programs currently in place have utilized an array of funding mechanisms. The most popular is bonds. Other funding sources include direct general appropriations and the dedication of special purpose taxes, such as a real estate transfer tax or a special district tax.

Benefits of a PDR Program

By purchasing the development rights to a parcel of farmland, a state or local government has accomplished more than just the protection of the land from development. It has helped to stabilize farmland values, thereby supporting the continuation of agriculture as a local industry. By removing its development value, the land becomes more affordable for agricultural

purposes, providing opportunities for area farmers to expand their operations or for young farmers to enter the business. Purchasing development rights on large blocks of farmland serves to bolster farmer confidence in the future of an area's agricultural industry, as well as encourage the continued existence of necessary support services vital to agriculture. PDR programs represent a strong measure of public support for farmers and farming.

Participating farmers benefit from the program by receiving a fair price for restricting their land. They continue to own and farm the land. AFT surveys have shown that the money received from selling development rights is often used to retire farm or other debt, purchase new farm equipment, enlarge or improve the farm, or to plan for retirement. If a farmer intends to pass the farm on to children or other heirs, the sale of development rights can reduce estate tax liabilities.

Benefits to the nonfarm community include: encouraging local food production; avoiding the high cost of servicing new developments; expanding the local economy; and protecting the rural character and quality of life associated with farming.

A purchase of development rights program provides an effective alternative to land development. It addresses the often frustrating escalation of land values due to nonfarm development pressures. Working in concert with complementary

programs directed at the economic, marketing, and operating needs of the farm community, PDR provides invaluable support to the agricultural industry.

American Farmland Trust Western Office 512 Second Street 4th Floor San Francisco CA 94107 (415) 543-2098

FARMLAND CONSERVATION TECHNIQUES - SUMMARY OF IMPLICATIONS TO CONTRA COSTA COUNTY & AGRICULTURAL PROPERTY OWNERS

	Program Element	Fiscal & Admin. Implications to Contra Costa County
1.	Purchase of Development Rights (PDR)	- need to develop eligibility criteria & priorities. - need to establish procedure to for determining value of development (see Appendix). - need to conduct property analysis - high capital expenditure of public funds on a per acre, per farm, or per transaction basis. - easement would need to be monitored by county or a non-profit land trust acting as its agent. Implications to Agric. Landowners - fee title remains in private ownership and property can be sold at anytime at its agric. value (eg. fair market value is reduced). - provides a one time capital infusion to farm or family. - results in a permanent development restriction on parcel although provisions can be made for allowing farm related residences or farm structures to be built. - provisions could be made that allow farmer to "buy" back the development rights if agricultural uses are no longer possible due to changed circumstances.
2.	Transfer of Development Rights (TDR)	- county or its agent would have to referee transfers. - county would need to designate elegible sending (eg. appropriate farmland) and receiving areas (eg. urban areas suitable for more intensive residential & commercial densities). - designation of receiving areas may require cooperation by incorporated cities, general plan modifications, and public imput/comment. - property analysis & baseline report needed for each transaction. - capital cost to protect farmland would be borne by the developers.

2.	Transfer of of Dev. Rights/con't	<u>Implications to Agric. Landowners</u> - landowners receive one time cash infusion in return for foregoing development rights. - value of development right determined by free market - farmland remains in private ownership with owner able to sell whenever he or she wants.
3.	Lease of Development Rights	<u>Fiscal & Admin. Implications to Contra Costa County</u> - need to develop eligibility criteria & priorities. - property analysis needed for each applicant. - depending on the length of term of contract, administrative costs to county (or its agent) would be higher than a PDR or TDR program, but capital expenditures would be much smaller than a PDR program that permanently acquires development rights on a parcel. <u>Implications to Agric. Landowners</u> - provides cash compensation to those landowners who agree to forego development on their land for a specific period of time.
4.	Clustering	<u>Fiscal & Admin. Implications to Contra Costa County</u> - need to develop eligibility criteria & priorities. - need to decide whether this can be applied to agric. parcels throughout the county, only in agricultural core, or only in designated portions of the agricultural core area (eg. on the edge of existing urban areas). - need to decide whether development restriction on residual portions would be permanent, for a specific length of time, or to operate concurrently with a county or area specific general plan. - modification to general plans may be required. - property analysis needed for each applicant.

4. Clustering/con't.

Fiscal & Admin. Implications to Contra Costa County

- no capital outlay of public funds required to protect residual portions of the agric. parcels involved.
- if not planned properly, could create further urban intrusions into agric. core and increase land use conflicts/conversion pressure in the agriculture core area.

Implications to Agric. Landowners

- allows for residential densities under current zoning to be concentrated on one portion of the agriculture parcel with development restricted on remaining portion of parcel.
- farmer may sell off parcel with enhanced development densities or retain for future development purposes.
- may cause conflicts between activities on adjacent farms and new residential property owners.

APPENDIX A: Alternative Methods of Establishing a Purchase Price for Conservation Transactions Involving a Purchase of Development Rights

1. Appraisal Method

Determine the difference between the property's Fair Market Value (FMV) and its Agricultural Value using a qualified private appraiser.

a. Using a before and after transaction appraisal process, make two separate determinations. First determine the property's full fair market value. Then secondly determine the property's agricultural value if all development rights have been removed from the property.

b. Subtract the second finding from the first value to determine the dollar value of the development right being given up.

Example:

Total Acres Offered	**Per Ac. Fair Market Value**	**Per Acre Agriculture Value**	**Difference**	**Total Development Rts. Value**
100 ac.	$15,000	$8,000	$7,000	$700,000

2. Standard per Acre Value

Determine a standard per acre value for development rights using a sliding scale to reflect different qualities of farmland and the parcel's distance from existing urban development or services. The value of this development right could be on a standard per acre basis or on a sliding scale to better reflect market pressures on different types of land and location differences (as shown below)

Example of Sliding Scale:

	Status of Property	**Soil Type**	**Development Rights Value per Acre**
a)	Inside a sphere of influence or within .5 miles of an urban service area	Class I Class II Class III	$4,000 $3,000 $2,500
b)	Within two miles of an urban service area or adjacent to a major highway intersection	Class I Class II-III	$1,500 $ 750

3. Bidding Procedure

Use the appraisal process to determine the property's fair market value (FMV) and its residual agricultural value. Based on the appraisal findings, allow the farmer to submit a bid for the sale of these development rights. Proposals could be selected for inclusion in the PDR program based on an evaluation of which transaction(s) represented the most important farmland (or highest valued) submitted for the lowest bid price.

Example: Comparing two different parcels; parcel A has class I soils and adjoins a sphere of influence, parcel B has class 3 soils and is 2 miles from the nearest existing urban services.

Total Acres Offered	Per Ac. Fair Market Value	Per Acre Agriculture Value	Difference	Total Development Rts. Value
A: 50 ac.	$15,000	$8,000	$7,000	$350,000
B:100 ac.	$ 7,000	$6,000	$1,000	$100,000

Bid Price Offered by Seller A: $175,000

Bid Price Offered by Seller B: $ 90,000

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Funding Sources for Farmland Conservation Programs in <u>Contra Costa County</u>

June 8, 1989

The following is a summary of potential sources of capital funds to support a farmland conservation program in Contra Costa County.

A. State Level Debt Financing

1. General Obligation Bonds

Must be passed by a vote of the electorate. Can be initiated either through a legislative bill approved by the Legislature and signed by the Governor or through the public initiative process.

Examples:

Agricultural Land Conservation Bond Act (A.B. 655)

* This bond measure, currently pending in the state legislature, would provide $200 million to local governments and private organizations to purchase development rights on farmland.

California Wildlife, Coastal, & Park Land Initiative (Proposition 70)

* Contra Costa County is eligible to use its per capita grant for farmland conservation activities.

B. State Level Land Conservation Fund Programs

1. California Environmental License Plate Fund
   * Administered by the Secretary of Resources, funds can be sought by the County for those projects resulting in a purchase of an easement on farmland for purposes of constructing a buffer zone to an existing or proposed park or natural area.

2. Renewable Resource Investment Fund (RRIF)
   * Administered by the Secretary of Resources, statutory guidelines allow appropriations of RRIF revenues for a variety of resource related projects including:
     - agricultural soil drainage programs.
     - support of technical assistance to prevent soil erosion.
     - agricultural and urban water conservation programs.

   The Governor's 1987-88 Budget allocated $ 2.7 million to the RRIF. These funds were disbursed to the State Department of Fish and Game, State

National Headquarters 1920 N Street NW Suite 400 Washington DC

C. County Level Public Debt Financing

1. County General Obligation Bonds
   * Approval required by a two-thirds vote of the county electorate. They have been used to finance farmland projects in other regions of the United States.

   Examples:
   Suffolk County, New York
   King County, Washington

   There are many people who believe that measure A A funds could be used for farmland conservation in eastern Contra Costa County. There would need to be a program developed and a strong commitment on the part of the Board of Supervisors for it to happen.

2. Certificates of Participation (COP's)
   * Certificates of participation financing instruments backed by a stream of lease payments, installment payments, or loan payments used by local government to acquire equipment, land, or facilities. COP's potentially could be used to maintain an agricultural district through long term lease financing. The county could structure a series of lease or installment payments for development rights on farmland within a given area. These lease agreements could then be pooled and sold to a bank or underwriter. The cost of each certificate would be included as a percentage interest in the lease payment stream.

   Example:
   City of Davis, CA

   * In 1987, the City of Davis attempted to issue a COP to purchase 466 acres of farmland. Under this innovative scheme, the city was to issue a 20 year COP and begin making payments on the land. The transaction was halted on procedural grounds.

D. General Fund Appropriations

   Examples:

   Forsythe County, North Carolina
   Boulder County, Colorado

E. Exactions or Developer Mitigation Fees

Developers could be charged by the County a per acre mitigation fee in circumstance where farmland is being annexed for development purposes. This could be applied towards administrative or acquisition expenses.

Examples:
San Joaquin County (and the City of Stockton)
City of Fairfield, Solano County
City of Carlsbad, San Diego County

* In agricultural areas near Carlsbad developers are paying a $5,000 acre development mitigation fee on 312 acres of coastal agricultural land being converted to commercial and residential use. These fees are being used to fund erosion being used to fund erosion improvements, purchase of easements, and other projects to enhance the productivity of the remaining 670 acres of farmland adjacent to Carlsbad.

F. Mello Roos Community Facilities Act

Under this act local governments are empowered to collect a special tax from designated community districts. To establish a CFD and levy a Mello Roos Tax, the county must follow a precise and detailed approval procedure of hearings and resolutions. The formation of the district must be approved by a two-thirds vote of residents within the area. Mello Roos Districts can also be authorized to produce revenue through the sale of municipal bonds. These bonds allow a local government to make land conservation expenditures while the special tax provides an annual revenue stream to retire the outstanding debt.

Examples:
City of Stockton (Spanos Park)
City of Fairfield, Solano County

* As part of an annexation proceeding in 1986, the City of Fairfield and Solano County formed a CFD on three ranches adjoining the Suisun Valley. Prior to development of these properties an annual tax ranging from 16 to 33 dollars is being levied. After the homes are built and sold, the tax rate increases to a flat rate of $80 per unit per year. These funds and CFD issued municipal bonds will support the farmland protection activities of the Solano County Farmland and Open Space Foundation.

G. Private Sources of Funds

If a private organization, such as a land trust, is involved in the implementation of the Contra Costa County program, some private sources of funding support may be available. Local land trusts throughout the state have been able to apply for and receive grant funds for administration or acquisition activities.

Examples:

Monterey County (affiliated non-profit is the Monterey Agricultural & Historical Land Conservancy)
Marin County (affiliated non-profit is the Marin Agricultural Land Trust)
Lancester County, PA (affiliated non-profit is Friends of Agricultural Land Preservation)

MONTEREY COUNTY AGRICULTURAL LAND INCENTIVE PROGRAM

Executive Summary

Monterey County is concerned with reducing development pressure on its agricultural land and addressing problems related to the down stream flooding of agricultural land. The County retained the services of the American Farmland Trust to develop a program based on economic incentives that would promote the continued use of farmland for agricultural purposes.

AFT working with representatives of the farm community has identified program objectives, acquisition procedures acceptable to landowners, project selection criteria, and priority areas within the county for program activities. Other activities conducted under this contract by AFT included an analysis of farmland sales for selected portions of the county, case studies suggesting the financial implications to a landowner of a conservation transaction, and an assessment of land conversion pressures on farmland adjacent to portions of the county experiencing urban growth pressure.

Recommended program objectives:

* protect the county's high valued soil, agricultural production capacity, and on-farm investments in irrigation and related infrastructure.
* limit urban expansion into areas of the County designated as "farmland" under the Monterey County General Plan.
* encourage future growth and development in areas of the county of less importance to agriculture.
* reduce soil erosion, flooding, and excessive run-off arising from conversion of up-slope farmland to non-agricultural uses.

Recommended Program Design Parameters:

* voluntary participation
* flexible program guidelines in order to respond to the needs of landowners, diverse land use constraints, and attract a range of funding sources.
* utilize a private organization, such as the Monterey County Agricultural & Historical Lands Conservancy, to assist with program activities.
* encourage equitable access by minimizing outside influences on the project application and selection process.

Recommended Farmland Conservation Options:

* purchase of development rights
* bargain sale of development rights
* purchase of an option to buy development rights
* purchase of a right of first refusal
* donation of a conservation easement

AFT, June '88

recycled paper

Recommended Program Eligibility Criteria:

* landowners with property designated under the Monterey County Land Use map as farmland and where preservation is consistent with the Monterey County General Plan.
* farmland parcels located within an existing Sphere of Influence should be considered only if conversion from an agricultural use will result in flooding, soil erosion, or other flood control problems for down-stream property owners.

Recommended Project Selection Criteria:

* parcel size
* soil quality & productivity of the parcel
* land use on adjoining properties and the probability that the adjoining properties will remain in agricultural use.
* impact the transaction will have on other farmland parcels in the area.
* other conservation benefits that will result due to the transaction.
* cost effectiveness of the transaction as compared to other proposed transactions with similar productivity values.
* imminent bankruptcy or other involuntary transfer that may result in the property no longer being in an agricultural use.
* demonstration impact
* amount of funds available

Recommended Priorities for Program Activities:

* Farmland located within one-half mile of a city boundary, unincorporated residential community, or industrial site should have first consideration in any review of applications. These priority areas, totaling 16,385 acres of farmland, include:

Salinas	Greenfield	Neponset
Chualar	King City	Castroville
Gonzales	Pajaro	
Soledad	Spreckels	

* Because of the flood and erosion hazards arising from conversion of farmland within Study Area I (between Highways 101 and Route 183 north west of Salinas), all farmland within this area should be included as a priority.

Recommended Program Administration:

* utilize a non-profit organization, such as the Monterey County Agricultural & Historical Land Conservancy, as an agent of the county to conduct landowner education, screen applications, conduct baseline analysis of proposed projects, initiate landowner negotiations, and conduct annual easement compliance monitoring.
* designate a department or county official to have primary responsibility for program activities, contacts with landowners, and any organizations acting on behalf of the county to implement this program.
* program procedures for conservation projects should include adoption of standard application form for use by landowners, project evaluation and negotiation, review by county officials and decision, final review of draft agreements by County Counsel, escrow proceedings, and periodic monitoring to ensure terms of the easement or agreement are being observed.
* implementation activities and schedule for Year I and II of the program.
* quarterly monitoring of progress and program evaluation by the County at the end of Year II.

<u>Other Administrative Considerations</u>:

* options to fund the program's initial operating costs are identified.
* in addition to funds already available under Proposition 70, the county should seek funds that would allow it to retain development rights on farmland for a period of time less than in perpetuity.
* the program's application form should include provision that allows the landowner to offer a bid price at which he/she is willing to give up rights to future development on the farmland parcel.
* to clarify the program's objectives for landowners and the public, the program should be entitled the Monterey County Farmland Conservation Program.

AFT has also included information on sources of funding for farmland conservation activities under county auspices using funds from existing state programs, debt financing at the state or county level, leveraging of development mitigation fees or special property taxes, and the potential of private sources of capital. Private non-profit organizations have been successful in obtaining charitable donations or matching grants from foundations or individuals to assist with operating expenses incurred through their involvement with local government farmland protection programs both in California and elsewhere.

Two other recommendations have been provided by AFT that may serve as policy incentives to the continued use of farmland but do not entail significant or on-going expenditures on the part of Monterey County. These include:

* adoption of a Right to Farm Ordinance
* consideration of a coordinated landowner education and public out-reach effort about this new county program with any existing county efforts to make landowners aware of procedures and benefits arising from placement of eligible farmland under a Land Conservation/Williamson Act contract.

Based on AFT's review of land use and farm real estate patterns within Monterey County, the general consensus on program issues achieved by representatives of the agricultural community through the Advisory Committee, and demonstrated interest by landowners and county officials for protection of Monterey County's agricultural resources; AFT is confident that a county sponsored farmland conservation program based on compensatory and economic incentives for voluntary farmland conservation has an excellent opportunity to be a success. This report is intended to assist the policy discussions and deliberations of county staff, county officials, and the public on this important new county approach to agricultural land resource protection.

CONTRA COSTA COUNTY AG PARK

I. GENERAL DESCRIPTION

A. Approximately 17,000 acres South and East of Brentwood.
B. Consisting of prime soils (Class I & II) presently serviced by BBID and ECCID irrigation districts.
C. Programs to benefit both farmers and the general public. (See Article VIII.)

II. RATIONALE FOR AG PARK COSTS

A. Ag lands require minimal community services and infrastructure; are cost effective use of lands.

1. By creating an Ag Park, the citizens of Contra Costa will be saving billions of dollars in taxes that otherwise would be needed (e.g. for major highway construction) were urban development allowed to take place in the area of the Ag Park.

B. The Ag Park will create an attraction in East Contra Costa similar to the kind now existing in the wine country of Napa Valley, thereby stimulating a diversity of related economies:

1. Tourism
2. Restaurants, hotels, inns, etc.
3. Recreational
4. Food industries and services.

C. The Ag Park will increase property values throughout East Contra Costa:

1. Thereby encouraging development of <u>quality</u> homes in surrounding areas (rather than low cost housing)
2. Thereby reducing population levels
3. Thereby reducing costs for services
4. Thereby increasing tax base for the area in general.

D. Increased tax base coupled with lower costs for the East County region resulting in greater overall revenues for the county as a whole. Ultimately, the Ag Park pays for itself.

III. TECHNIQUES TO CREATE THE AG PARK

A. Initial program to study formation and funding of Ag Park.

1. Apply for study grants:
   a. University of California Sustainable Agriculture Grant Program.

b. CCC Resource Conservation District.
c. CCC Planning Department.

2. Seek consultant and staff assistance from:
   a. UC Coop Extension Service.
   b. California Association of Family Farmers.
   c. Calif. Dept. of Agriculture.

B. Purchase of Development Rights Program.

1. County would purchase development rights from landowner. Parcel would then become part of the Ag Park:
   a. Subject to the rules, limitations and requirements for land use within the Ag Park.
   b. Eligible for participation in all Ag Park programs.

2. PDR program is voluntary.

3. Standardized formula (including appraisal system) will be used to determine value of development rights for each parcel.

4. PDR program sets criteria for eligibility and selection of parcels for inclusion in Ag Park.

C. Fee simple sale or donation of lands to Ag Park.

D. Special District created by county for Ag Park.

IV. FUNDING

A. The funds to create the Ag Park land would be generated from broad-based county-wide sources:

1. real estate transfer tax
2. annual "special district" property tax assessment
3. mitigation fees from developments
4. Mello-Roos benefit assessment district
5. East Bay Regional Park District
6. Special Grants from foundations; other private sources.
7. General obligation bonds.

V. STRUCTURE OF THE AG PARK

A. Ag Park will be a "special district" created by Board of Supervisors.

1. Board of Directors to be made up of members from the Ag Park community.
2. Board of Directors to be elected by the Ag Park community.
3. "Board" gets operational funds from the Ag Park

Land Trust.

4. "Board" regulates and administers all Ag Park programs.

    a. "Board" has power to appoint committees or hire firms to carry out programs.
    b. "Board" establishes criteria and sets standards for programs and projects.

5. "Board" sets land use standards and restrictions.
6. "Board" has power to approve or disapprove building permits issued within Ag Park boundaries and to inspect construction of said buildings.
7. "Board" governed by "Charter" of the Ag Park and answers to the county Board of Supervisors.
8. "Board" acts as a regional planning commission making recommendations to Board of Supervisors.

B. Annual Meeting of Ag Park Landowners.

1. Landowners can present proposals or petitions to "Foundation."
2. Election of board members held at annual meeting.

VI. AG PARK INFRASTRUCTURE

A. Water for irrigation

1. The viability and economic feasability of agriculture depends on water at reasonable cost.
2. The County will make every effort to support existing irrigation districts' abilities to deliver water at reasonable costs.

    a. When Los Vaqueros Reservoir is built, water will be made available at reasonable cost to Ag Park.

B. Highways and roads.

1. State and County to reroute Highway 4 around Ag Park (or build Park Way through Ag Park) to reduce risk of accidents between slow-moving farm vehicles and fast-moving highway traffic.

2. Local traffic permissible in Ag Park at slow speeds.

C. Farm worker housing.

1. Provisions for on-farm employee housing.

2. Standards to be set by "Board."

D. Ag services businesses permitted.

E. Ag Park Community Center.

1. Conducts social events,
2. Coordinates and facilitates farmer/farm worker activities.
3. Develop and administer work/study programs for entry level farmers, students and farm workers.
4. Conducts language classes in English and Spanish.
5. Conduct classes for home canning, food processing, cooking, etc.

VII. Taxation

A. Ag Park lands to be taxed on basis of agricultural values.

B. Williamson Act could apply.

VIII. Ag Park Programs

A. Educational programs.

1. Field trips throughout growing season for Contra Costa schools, kindergarten through high school. Students gain knowledge of where food comes from and how it is produced.
2. On-farm work-study programs for college level students.
3. Cooperation with University of California, Berkeley, on research projects needing field applications.
4. U.C. Coop Extension office to be based in Brentwood.

B. Museum on "History of Agriculture in California."

C. Cooperative food processing facilities.

1. For use by growers to develop product lines (such as juices, jams, dried fruits, sauces, cheeses, baked goods).
2. For use by consumers who pick their fruits or vegetables at nearby Ag Park farms.
3. Facilities for packing and labeling product lines for growers.

D. Develop promotional campaigns for "Contra Costa Grown" products along with marketing and distribution strategies.

IX. Issues related to the Ag Park.

A. The Ag Park Community.

1. The Ag Park community is defined as all people living or working in the Ag Park.

a. landowners farming their own land.

b. farmers farming rented lands in Ag Park.
c. residents living within Ag Park boundaries.
d. farm workers.
e. businesses located in Ag Park.

B. One purpose of the Ag Park is to enhance, protect and sustain the Ag Park community.

C. Another purpose of the Ag Park is educational:

1. Teach young people of Contra Costa where food comes from.
2. Create greater understanding and respect for agriculture by urban dwellers.
3. Develop ways to make agriculture sustainable.
4. Fresher, healthier food produced locally.

D. Another purpose of the Ag Park is to preserve a large area of our most basic resource - land for food production.

E. By preserving land for farms, we also maintain open space, thereby enhancing the quality of life for all Contra Costa residents in many ways.

X. Questions Related to Ag Park

A. How to maintain healthy competition within Ag Park economy?

B. How to prohibit non-agricultural uses?

C. How to encourage entry-level young farmer to get started farming with eventual ability to buy land?

D. How to assure that serious family farmers (or serious potential farmers) will be able to buy Ag Park lands and not be pushed out by hobby farmers or agribusinesses?

E. Is it necessary to put maximum acreage limits on how much acreage can be controlled by any one farmer (e.g. precedent set in State of Nebraska, SB 300) in order to assure that enough parcels are always available to maintain a viable Ag Park community?

F. Is it necessary to put minimum acreage limits on parcel sizes?

APPENDIX H

AIR QUALITY TECHNICAL ANALYSIS

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AIR QUALITY IMPLICATIONS OF THE CONTRA COSTA COUNTY GENERAL PLAN

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OCTOBER 1988

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I. AIR POLLUTANTS AND STANDARDS

The Mulford-Carrell Act of 1969 and the Clean Air Act of 1970 established state and federal air quality standards for several pollutants. These standards are divided into primary standards, designed to protect the public health, and secondary standards, intended to protect the public welfare from effects such as visibility reduction, soiling, nuisance and other forms of damage. These standards are in the form of maximum durations of concentrations, and are shown below in Table 1.

The air pollutants covered in the above-described legislation are known as "criteria" pollutants, in that their effects are documented in criteria documents which form the basis for federal and state ambient air quality standards. These pollutants and their effects are described below.

Suspended Particulate Matter

Suspended particulate matter consists of solid and liquid particles of dust, soot, aerosols and other matter which are small enough to remain suspended in the air for a long period of time. A portion of the suspended particulate matter in the air is due to natural sources such as wind blown dust and pollen. Man-made sources include combustion, automobiles, field burning, factories and unpaved roads.

The effects of high concentrations on humans include aggravation of chronic disease and heart/lung disease symptoms. Non-health effects include reduced visibility and soiling of surfaces.

Carbon Monoxide

Carbon monoxide is an odorless, colorless gas that is highly toxic. It is formed by the incomplete combustion of fuels, and it main source in the Bay Area is automobiles.

Table 1: Federal and State Ambient Air Quality Standards

Pollutant	Averaging Time	Federal Primary Standard	State Standard
Ozone	1-Hour	0.12 PPM	0.10 PPM
Carbon Monoxide	8-Hour	9.0 PPM	9.0 PPM
	1-Hour	35.0 PPM	20.0 PPM
Nitrogen Dioxide	Annual	0.05 PPM	---
	1-Hour	---	0.25 PPM
Sulfur Dioxide	Annual	0.03 PPM	---
	24-Hour	0.14 PPM	0.05 PPM
	1-Hour	---	0.5 PPM
Suspended Particulates	Annual	50 ug/m^3	30 ug/m^3
	24-Hour	150 ug/m^3	50 ug/m^3
Lead	30-Day Ave.	---	1.5 ug/m^3
	3-Month Ave	1.5 ug/m^3	---

Carbon monoxide's health effects are related to its affinity for hemoglobin in the blood. At high concentrations, carbon monoxide reduces the amount of oxygen in the blood, causing heart difficulties in people with chronic diseases, reduced lung capacity and impaired mental abilities.

Ozone

Ozone is the most prevalent of a class of photochemical oxidants formed in the urban atmosphere. The creation of ozone is a result of

a complex chemical reactions between hydrocarbons and oxides of nitrogen in the presence of sunshine. Unlike other pollutants, ozone is not released directly into the atmosphere from any sources. The major sources of oxides of nitrogen and hydrocarbons, known as ozone precursors, are combustion sources such as factories and automobiles, and evaporation of solvents and fuels.

The health effects of ozone are eye irritation and damage to lung tissues. Ozone also damages some materials such as rubber, and may damage plants and crops.

Nitrogen Dioxide

Nitrogen dioxide is a reddish-brown toxic gas. It is one of the oxides of nitrogen that result from combustion. It is the only oxide of nitrogen which is toxic; however, other oxides of nitrogen, particularly nitric oxide, are converted to nitrogen dioxide in the presence of sunshine. Major sources of oxides of nitrogen are automobiles and industry.

Sulfur Dioxide

Sulfur dioxide is a colorless gas with a pungent, irritation odor. It is created by the combustion of sulfur-containing fuels. This substance is known to oxidize to sulfur trioxide, which combines with moisture in the atmosphere to form a sulfuric acid mist.

Sulfur dioxide damages and irritates lung tissue, and accelerates corrosion of materials.

Lead

Atmospheric lead occurs in the form of airborne lead particles. The dominant source of lead in urban atmospheres is lead compounds contained in gasoline.

Lead accumulates in the body tissues, where it impairs blood function and nerve construction.

Toxic Air Pollutants

In addition to the above "criteria" pollutants for which there are ambient air quality standards, there is a second class of regulated pollutants known as toxic (or hazardous) pollutants. These are known to be injurious, even is small quantities, but are relatively uncommon. There are emission limitations for these pollutants, rather than ambient air quality standards. To date, hazardous pollutants regulated by the Bay Area Air Quality Management District (BAAQMD) are asbestos, beryllium, mercury, vinyl chloride and benzene.

II. LOCAL AND REGIONAL INFLUENCES ON AIR QUALITY

The amount of a given pollutant in the atmosphere is determined by the amount of pollutant released and the atmosphere's ability to transport and dilute the pollutant. The major determinants of transport and dilution are wind, atmospheric stability, terrain and, for photochemical pollutants, sunshine.

Atmospheric stability refers to the tendency of the atmosphere's thermal stratification to suppress or promote vertical mixing of pollutants. The occurrence of high atmospheric stability, known as inversion conditions, severely reduces vertical mixing of pollutants.

Atmospheric stability is measured in the Bay Area twice daily by radiosondes released at Oakland Airport. During the summer, inversions are generally elevated above ground level, but are present over 90% of the time in both the morning and afternoon. In winter surface-based inversions dominate in the morning hours, but frequently dissipate by afternoon.

The western portions of the county show a very strong influence of winds through the Golden gate. Ventilation in this area is very good,

winds are persistent and strong and calms are relatively infrequent. Although heavily urbanized, this portion of the county has very good air quality due to the good ventilation characteristics, cool temperatures and lack of upwind pollutants.

Wind data for the inland Diablo-San Ramon Valley show a strong influence of terrain on wind. (Ref. 1) Winds are channelled by terrain, and the area is very sheltered, with relatively low average wind speeds and a very high frequency of calm conditions. The potential for air pollution in this area is high because of reduced ventilation and warm temperatures which promote the formation of ozone. This area is also downwind from the highly urbanized areas of western Contra Costa and Alameda counties.

The northern portions of the county from the Carquinez Straits eastward along the Sacramento River have good ventilation characteristics. The area is exposed to winds both from the west and east, and terrain provides little protection from the wind. Average wind speed measured in Pittsurg is relatively high, and calm conditions are quite infrequent. This area contains a large portion of the industrial sources of pollutants within the county and is located downwind of both the greater Bay Area and the Diablo Valley.

The eastern portions of the county are generally well ventilated by winds flowing through the Carquinez Straits and Delta. Terrain does not restrict ventilation, but temperatures are quite warm, promoting the formation of ozone. This portion of the county is very lightly urbanized, but is exposed to pollutants transported into the area from the greater Bay Area.

III. AIR POLLUTION SOURCES

Contra Costa County contains a multitude of air pollutions sources. The combustion of fuel for space and water heating, industrial processes and commercial uses is one such pollutant source. The evaporation of fuels and solvents, incineration, fires, agricultural tilling

and pesticide uses are other examples of typical pollutant sources. The largest single source of pollutants is vehicles, which in Contra Costa County are responsible for 76% of the emitted carbon monoxide, 29% of the emitted oxides of nitrogen, 36% of the emitted hydrocarbons, and 5% of the emitted particulates and sulfur dioxide. Table 2 shows the breakdown of Contra Costa County emissions by source for 5 pollutants.

IV. PAST AND CURRENT AIR QUALITY

The Bay Area Air Quality Management District operates a network of permanent air quality monitoring sites throughout the Bay Area. The District has for several years operated a multi-pollutant monitoring sites in Contra Costa County at Richmond, Concord, Pittsburg and Bethel Island. Data for gaseous pollutants from these sites for the years 1984-1988 is shown in Table 3 below.

Each of the four air quality monitoring sites in Contra Costa County measure ozone, carbon monoxide, nitrogen dioxide, and sulfur dioxide. Suspended particulates are measured at the Concord and Bethel Island stations. Levels of pollutants meet all the state and federal standards with the exception of ozone and suspended particulates. Occurrences of concentrations exceeding the ozone and particulate standards are shown in Table 3 below.

Table 3 shows that ozone air quality varies greatly within Contra Costa County. Richmond, located on the western edge of the county and exposed to winds through the Golden Gate did not measure a single exceedance of the state or federal standards for ozone in the period 1984-1988. Further inland, Concord experienced between 5-20 days each year above the state standard, and from 0-3 days per year above the federal standard. Ozone levels at Pittsburg and Bethel Island were somewhat lower than those at Concord, but still exceeded the state ozone standard on 1 to 14 days per year and the federal standard up to 2 days per year.

Table 2: Daily Contra Costa County Emissions, in Tons Per Day.

Source	Daily Emissions, in Tons Per Day				
	PART	ROG	NOX	SO2	CO
Petroleum Refining	3.5	28.8	36.9	37.9	3.7
Chemical/Industrial/ Commercial Processes	27.5	10.3	3.3	7.2	33.5
Organic Compounds Evap.	---	18.9	---	---	---
Combustion	5.2	3.1	43.1	3.8	37.9
Off-Highway Vehicles	0.3	3.8	4.4	2.1	17.5
Aircraft	---	0.2	0.1	---	4.1
Motor Vehicles	4.9	42.0	36.4	2.3	308.1
Misc. Sources	53.3	8.0	---	---	0.9
Total	95.0	115.0	124.0	53.1	406.0

PART = Particulate

ROG = Reactive Organic Gases (Hydrocarbons)

NOX = Oxides of Nitrogen

SO2 - Sulfur Dioxide

CO = Carbon Monoxide

Source: Ref. 2

Table 3: Summary of Air Quality Data for Contra Costa County

Site	Number of Day Exceeding Standard in:				
	1984	1985	1986	1987	1988
OZONE (STATE STANDARD = 0.09 PPM)					
Richmond	0	0	0	0	0
Concord	15	10	5	20	10
Pittsburg	9	3	1	14	8
Bethel Island	11*	8	8	14	7
OZONE (FEDERAL STANDARD = 0.12 PPM)					
Richmond	0	0	0	0	0
Concord	3	1	0	3	1
Pittsburg	1	1	0	2	0
Bethel Island	1*	2	0	0	0
SUSPENDED PARTICULATE (STATE STANDARD = 50 ug/m3)[1]					
Richmond	--	--	--	--	--
Concord	--	--	4*	6	10
Pittsburg	--	--	--	--	--
Bethel Island	--	2*	3*	5	14

[1] Suspended particulate is measured every sixth day.

* Period of measurement was less than a complete year.

PPM = Parts Per Million

ug/m3 = Micrograms per Cubic Meter

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The ambient air quality standards for suspended particulate were modified to include only fine particulates, known as PM-10, (aerodynamic diameter 10 microns or less) rather than total suspended particulate (aerodynamic diameter less than 30 microns) in 1984 (state) and 1987 (federal). Monitoring for PM-10 at the Bethel Island site began in 1985 and at the Concord site began in 1986.

There is considerable difference between the state and federal standards for suspended particulate. Standards exist for 24 hour concentrations and annual average concentrations. Based upon the limited period of record at the Bethel Island and Concord monitoring sites it appears that both the 24 hour and annual federal standards are met in Contra Costa County. The state annual standard is also met, but the state 24-hour standard is exceeded, as shown in Table 3.

V. REGIONAL AIR QUALITY PLANNING

The U.S. Clean Air Act Amendments of 1977 required that each state identify areas within its borders that do not meet federal primary standards as non-attainment areas. The states were required to prepare a State Implementation Plan (SIP) to show how the federal standards were to be attained by 1987. The Bay Area portion of the SIP was the <u>1982 Bay Area Air Quality Plan</u>.

Despite considerable improvement in air quality, the Bay Area did not meet the 1987 deadline for attainment of the federal air quality standards. Subsequently, the U. S. Environmental Protection Agency has adopted interim policies regarding post-1987 non-attainment areas. These policies give non-attainment areas until the end of 1990 to revise the SIP to demonstrate attainment and maintenance of the standards. After submittal of the revised SIP the EPA would classify non-attainment ares as near-term (3-5 years) or long term (more than 5 years). For near term non-attainment areas pollutant reductions of 3% per year would have to occur until standards are attained, and maintenance of the standard for a period of 10 years would have to be demon-

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Although the state of California has had its own ambient air quality standards for many years, but until recently there was no requirement that these standards be attained by any date. The California Clean Air Act was signed into law on January 2, 1989. This legislation requires areas that exceed the California ambient air quality standards to plan for the eventual attainment of the standards. The time given to various areas would depend on the severity of air quality problems. Areas classified as "moderate" would have until 1994 to attain the state standards, while "serious" and "severe" areas would have until 1997 and beyond, respectively.

VI. FUTURE AIR QUALITY

Future growth in Contra Costa County would have impacts upon local and regional air quality. The primary effect of development would be indirect, that is, due to automobile traffic generated by new land uses. This automobile traffic would affect local carbon monoxide concentrations near roads and intersections, but would also affect the regional air quality of the County and areas to the east.

Local Impacts

On the local scale carbon monoxide has been considered the most important pollutant. The CALINE-4 computer model was applied to 6 critical roadway segments, selected as having the highest traffic demand to capacity ratio in the year 2005. These roadway segments would have the highest traffic volumes and greatest congestion within the county, and should be the locations with the greatest potential for carbon monoxide problems.

Because of the extended period of congestion forecast for the locations studied, special consideration had to be given to the relationship of 1-hour concentrations predicted by the CALINE-4 model and the calculated 8-hour averaged concentrations derived from the model runs.

As traffic demand grows beyond the capacity of a roadway, there is an upper limit on the peak hour traffic flow. Excess traffic demand shifts to the hour before and after the peak hour, essentially "flattening" out the traffic peak. If a modelling method includes only peak hour traffic, peak 1-hour concentrations will not increase beyond a certain limit once a roadway reaches capacity. The volumes shifted to other hours would, however, affect the peak 8-hour concentration of carbon monoxide. There is a need, therefore, for the modelling approach to account for traffic over a longer period than just the peak hour.

The CALINE-4 model was used to predict future levels of carbon monoxide for the peak 1-hour period and for eight 1-hour periods constituting the 8-hour peak traffic period. The roadway was assumed to be at capacity for 3 consecutive hours during the 8-hour period. The meteorological conditions for the peak and off-peak periods during the 8-hour period was taken from a California Department of Transportation publication.(Ref. 4)

The CALINE-4 model is a fourth-generation line source air quality model that is based on the Gaussian diffusion equation and employs a mixing zone concept to characterize pollutant dispersion over the roadway (Ref. 5). Given source strength, meteorology, site geometry and site characteristics, the model predicts pollutant concentrations for receptors located within 150 meters of the roadway. The CALINE-4 model allows roadways to be broken into multiple links that can vary in traffic volume, emission rates, height, width, etc.. Receptors (locations where the model calculates concentrations) were located at distances of 100 feet and 200 feet from the outside traffic lane. Since all the segments modeled are freeways 100 feet from the closest traffic lane was selected as an estimate of the closest a person might be expected to be for at least a 1-hour period.

Emission factors were derived from the California Air Resources Board EMFAC-7PC computer model. Adjustments were made for vehicle mix and

hot start/cold start/ hot stabilized percentages appropriate to each roadway. Temperature was assumed to be 40 degrees F. The emissions factors were adjusted downward to reflect the current estimated effectiveness of the Inspection and Maintenance program in reducing carbon monoxide emissions. (Ref. 6)

The computation of 1-hour carbon monoxide levels assumed the following meteorological conditions:

Windspeed: 0.5 meters per second
Stability: G Category
Mixing Height: 100 meters
Surface Roughness: 150 cm
Standard Deviation of Wind Direction: 10 degrees

The computation of 8-hour carbon monoxide levels assumed the following meteorological conditions:

Windspeed: 1.0 meters per second
Stability: G Category
Mixing Height: 100 meters
Surface Roughness: 150 cm
Standard Deviation of Wind Direction: 20 degrees

The CALINE-4 model calculates the local contribution of nearby roads to the total concentration. The other contribution is the background level attributed to more distant traffic. Background levels were calculated separately for each location using a methodology recommended by the Bay Area Air Quality Management District. (Ref. 7)

Predicted future carbon monoxide concentrations near the selected road segments are shown below in Table 4. The data is in parts per million (PPM).

The predicted concentrations shown in Table 4 are to be compared with the federal and state ambient air quality standards. The federal

Table 4: Predicted Year 2005 Carbon Monoxide Concentrations, in Parts Per Million.

Location	Peak 1-Hour		Peak 8-Hour[1]		8-Hour (Peak)		8-Hour (Off Peak)	
	100'	200'	100'	200'	100'	200'	100'	200'
I-80 bet. Appian and S.R. 4	15.5	12.8	6.2	5.5	8.7	7.2	4.7	4.4
I-80 bet. Gilman and San Pablo	16.1	13.3	6.4	5.6	9.1	7.5	4.8	4.4
S.R. 24 East of Caldecott Tunnel	15.6	13.0	6.2	5.5	8.8	7.3	4.7	4.4
I-680 bet. Alcosta and Bollinger	14.3	11.4	6.3	5.5	8.9	7.3	4.7	4.4
S.R. 4 East of Port Chicago	16.8	14.0	6.4	5.5	9.0	7.4	4.8	4.4
S. R. 4 bet. Railroad and Lonetree	12.9	11.0	5.5	4.9	7.1	6.1	4.4	4.2

[1] The 8-hour peak concentration is calculated assuming 3 hours of 8-hour (peak) conditions followed by 5 hours of 8-hour (off-peak) conditions.

1-hour standard is 35 PPM, the corresponding state standard is 20 PPM. The federal and state 8-hour standards are both 9 PPM. The concentrations in Table 4 are all below the state and federal standards.

Regional Impacts

Vehicle trips generated by land uses within Contra Costa County would create new emissions over the entire Bay Area transportation network. Year 2005 emissions from mobile sources within Contra Costa County were estimated using output from the transportation system modeling performed as part of the general plan revisions studies. The transportation model output for year 2005 Vehicle Miles Travelled was available stratified by five roadway types and five area types. Speed data was available also for each roadway/area type combination. Speed data is shown in Table 5.

Daily VMT on each type of roadway is shown in Table 6 for the year 2005. A spread sheet program was used to multiply these VMT figures by the appropriate emission factor for each pollutant based upon the estimated average speed for the road type/area type combination. The assumed emission factors in grams per mile are shown in Table 7. These emissions factors were derived from the EMFAC7-PC computer program with appropriate assumptions for Inspection and Maintenance Program effectiveness. Emissions factors are shown for three pollutants: reactive organics (ROG), carbon monoxide (CO) and oxides of nitrogen (NOx).

The resulting emission estimates for ROG, CO and NOx are shown in Table 8. Also shown are current Contra Costa County emissions from on-road mobile sources. Future emissions from autos are considerable below current levels, despite anticipated traffic growth, due to the increasing effectiveness of emission controls and existing programs such and the Inspection and Maintenance Program.

While Table 8 shows that vehicle emissions within Contra Costa County will be decreasing in the future, other categories of emissions will be increasing. As population and employment grow other categories of emission generators will be increasing. Consumer and industrial solvent use, fuel combustion, evaporative losses from gasoline transfer, and industrial process emissions will all be increasing along with

Table 5: Free-Flow Speeds by Roadway Type and Area Type

	Roadway Type				
	Freeway	Express-way	Minor Arter.	Collector	Major Arter.
Area Type:					
Core	40	35	8	8	12
CBD	45	40	12	10	15
CBD (Outlying)	50	40	20	15	25
Residential	55	45	25	20	50
Rural	60	50	45	40	50
HOV Lanes	50	--	--	--	--

population and employment. These increases would offset some of the decreases expected in vehicle emissions.

The growth in emissions associated with growth accommodated within the general plan would contribute to the continuing ozone problem in central and east Contra Costa County. Because ozone is a photochemical pollutant that is formed over a period of hours the effect of project emissions on ozone levels would also be felt further east in the Sacramento and San Joaquin Valley air basins.

Table 6: Year 2005 Vehicle Miles Travelled by Roadway Type and Area Type

DAILY VMT 2005

AREA TYPE	FREEWAY	EXPRESS	MIN ART	COLLECT	MAJ ART	TOTAL
CORE	0	0	0	0	0	0
CBD	53640	0	5128	0	11131	69899
OUTLYING CBD	58182	28286	31842	1194	226953	346457
RESIDENT.	5565266	718600	880964	231524	3967983	11364338
RURAL	342471	365451	461672	89888	664418	1923900
HOV LANES	4571996	0	0	0	0	4571996

Table 7: Emissions Factors by Roadway Type and Area Type, in Grams/Mile

ROG EMISSION FACTORS. GMS/MILE

AREA TYPE	FREEWAY	EXPRESS	MIN ART	COLLECT	MAJ ART
CORE	0.9	1	3.3	3.3	2.7
CBD	0.8	0.9	2.7	2.9	2.3
OUTLYING CBD	0.7	0.9	1.8	2.3	1.5
RESIDENT.	0.6	0.8	1.5	1.8	1.2
RURAL	0.6	0.7	0.6	0.9	0.7
HOV LANES	0.7	0.7	0.7	0.7	0.7

CO EMISSION FACTORS. GMS/MILE

AREA TYPE	FREEWAY	EXPRESS	MIN ART	COLLECT	MAJ ART
CORE	8.7	10.6	35.8	35.8	29.5
CBD	7.2	8.7	29.5	32.2	25.4
OUTLYING CBD	6	8.7	20.3	25.4	16.3
RESIDENT.	5.1	7.2	16.3	20.3	13.1
RURAL	5.1	6	7.2	8.7	6
HOV LANES	6	6	6	6	6

NOX EMISSION FACTORS. GMS/MILE

AREA TYPE	FREEWAY	EXPRESS	MIN ART	COLLECT	MAJ ART
CORE	1.6	1.6	2.1	2.1	1.9
CBD	1.6	1.6	1.9	2	1.8
OUTLYING CBD	1.7	1.6	1.7	1.8	1.6
RESIDENT.	1.8	1.6	1.6	1.7	1.6
RURAL	1.8	1.7	1.6	1.6	1.7
HOV LANES	1.7	1.7	1.7	1.7	1.7

Table 8: Year 2005 and Current On-Road Mobile Source Emissions, Tons per Day

	ROG	CO	NOx
Year 2005	17.1	165.4	34.2
Current	42.0	308.1	36.4

VII. REFERENCES

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2. Bay Area Air Quality Management District, Base Year 1983 Emissions Inventory Summary Report, August 1987.

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6. California I/M Review Committee, Evaluation of the California Smog Check Program, April 1987.

7. Bay Area Air Quality Management District, Air Quality and Urban Development-Guidelines, 1985.

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The CALINE-4 model was used to predict future levels of carbon monoxide for the peak 1-hour period and for eight 1-hour periods constituting the 8-hour peak traffic period. The roadway was assumed to be at capacity for 3 consecutive hours during the 8-hour period. The meteorological conditions for the peak and off-peak periods during the 8-hour period was taken from a California Department of Transportation publication.(Ref. 4)

The CALINE-4 model is a fourth-generation line source air quality model that is based on the Gaussian diffusion equation and employs a mixing zone concept to characterize pollutant dispersion over the roadway (Ref. 5). Given source strength, meteorology, site geometry and site characteristics, the model predicts pollutant concentrations for receptors located within 150 meters of the roadway. The CALINE-4 model allows roadways to be broken into multiple links that can vary in traffic volume, emission rates, height, width, etc.. Receptors (locations where the model calculates concentrations) were located at distances of 100 feet and 200 feet from the outside traffic lane. Since all the segments modeled are freeways 100 feet from the closest traffic lane was selected as an estimate of the closest a person might be expected to be for at least a 1-hour period.

Emission factors were derived from the California Air Resources Board EMFAC-7PC computer model. Adjustments were made for vehicle mix and

hot start/cold start/ hot stabilized percentages appropriate to each roadway. Temperature was assumed to be 40 degrees F. The emissions factors were adjusted downward to reflect the current estimated effectiveness of the Inspection and Maintenance program in reducing carbon monoxide emissions. (Ref. 6)

The computation of 1-hour carbon monoxide levels assumed the following meteorological conditions:

Windspeed: 0.5 meters per second
Stability: G Category
Mixing Height: 100 meters
Surface Roughness: 150 cm
Standard Deviation of Wind Direction: 10 degrees

The computation of 8-hour carbon monoxide levels assumed the following meteorological conditions:

Windspeed: 1.0 meters per second
Stability: G Category
Mixing Height: 100 meters
Surface Roughness: 150 cm
Standard Deviation of Wind Direction: 20 degrees

The CALINE-4 model calculates the local contribution of nearby roads to the total concentration. The other contribution is the background level attributed to more distant traffic. Background levels were calculated separately for each location using a methodology recommended by the Bay Area Air Quality Management District. (Ref. 7)

Predicted future carbon monoxide concentrations near the selected road segments are shown below in Table 4. The data is in parts per million (PPM).

The predicted concentrations shown in Table 4 are to be compared with the federal and state ambient air quality standards. The federal

Table 4: Predicted Year 2005 Carbon Monoxide Concentrations, in Parts Per Million.

Location	Peak 1-Hour		Peak 8-Hour[1]		8-Hour (Peak)		8-Hour (Off Peak)	
	100'	200'	100'	200'	100'	200'	100'	200'
I-80 bet. Appian and S.R. 4	15.5	12.8	6.2	5.5	8.7	7.2	4.7	4.4
I-80 bet. Gilman and San Pablo	16.1	13.3	6.4	5.6	9.1	7.5	4.8	4.4
S.R. 24 East of Caldecott Tunnel	15.6	13.0	6.2	5.5	8.8	7.3	4.7	4.4
I-680 bet. Alcosta and Bollinger	14.3	11.4	6.3	5.5	8.9	7.3	4.7	4.4
S.R. 4 East of Port Chicago	16.8	14.0	6.4	5.5	9.0	7.4	4.8	4.4
S. R. 4 bet. Railroad and Lonetree	12.9	11.0	5.5	4.9	7.1	6.1	4.4	4.2

[1] The 8-hour peak concentration is calculated assuming 3 hours of 8-hour (peak) conditions followed by 5 hours of 8-hour (off-peak) conditions.

1-hour standard is 35 PPM, the corresponding state standard is 20 PPM. The federal and state 8-hour standards are both 9 PPM. The concentrations in Table 4 are all below the state and federal standards.

Regional Impacts

Vehicle trips generated by land uses within Contra Costa County would create new emissions over the entire Bay Area transportation network. Year 2005 emissions from mobile sources within Contra Costa County were estimated using output from the transportation system modeling performed as part of the general plan revisions studies. The transportation model output for year 2005 Vehicle Miles Travelled was available stratified by five roadway types and five area types. Speed data was available also for each roadway/area type combination. Speed data is shown in Table 5.

Daily VMT on each type of roadway is shown in Table 6 for the year 2005. A spread sheet program was used to multiply these VMT figures by the appropriate emission factor for each pollutant based upon the estimated average speed for the road type/area type combination. The assumed emission factors in grams per mile are shown in Table 7. These emissions factors were derived from the EMFAC7-PC computer program with appropriate assumptions for Inspection and Maintenance Program effectiveness. Emissions factors are shown for three pollutants: reactive organics (ROG), carbon monoxide (CO) and oxides of nitrogen (NOx).

The resulting emission estimates for ROG, CO and NOx are shown in Table 8. Also shown are current Contra Costa County emissions from on-road mobile sources. Future emissions from autos are considerable below current levels, despite anticipated traffic growth, due to the increasing effectiveness of emission controls and existing programs such and the Inspection and Maintenance Program.

While Table 8 shows that vehicle emissions within Contra Costa County will be decreasing in the future, other categories of emissions will be increasing. As population and employment grow other categories of emission generators will be increasing. Consumer and industrial solvent use, fuel combustion, evaporative losses from gasoline transfer, and industrial process emissions will all be increasing along with

Table 5: Free-Flow Speeds by Roadway Type and Area Type

	Roadway Type				
	Freeway	Express-way	Minor Arter.	Collector	Major Arter.
Area Type:					
Core	40	35	8	8	12
CBD	45	40	12	10	15
CBD (Outlying)	50	40	20	15	25
Residential	55	45	25	20	50
Rural	60	50	45	40	50
HOV Lanes	50	--	--	--	--

population and employment. These increases would offset some of the decreases expected in vehicle emissions.

The growth in emissions associated with growth accommodated within the general plan would contribute to the continuing ozone problem in central and east Contra Costa County. Because ozone is a photochemical pollutant that is formed over a period of hours the effect of project emissions on ozone levels would also be felt further east in the Sacramento and San Joaquin Valley air basins.

Table 6: Year 2005 Vehicle Miles Travelled by Roadway Type and Area Type

DAILY VMT 2005

AREA TYPE	FREEWAY	EXPRESS	MIN ART	COLLECT	MAJ ART	TOTAL
CORE	0	0	0	0	0	0
CBD	53640	0	5128	0	11131	69899
OUTLYING CBD	58182	28286	31842	1194	226953	346457
RESIDENT.	5565266	718600	880964	231524	3967983	11364338
RURAL	342471	365451	461672	89888	664418	1923900
HOV LANES	4571996	0	0	0	0	4571996

Table 7: Emissions Factors by Roadway Type and Area Type, in Grams/Mile

ROG EMISSION FACTORS, GMS/MILE

AREA TYPE	FREEWAY	EXPRESS	MIN ART	COLLECT	MAJ ART
CORE	0.9	1	3.3	3.3	2.7
CBD	0.8	0.9	2.7	2.9	2.3
OUTLYING CBD	0.7	0.9	1.8	2.3	1.5
RESIDENT.	0.6	0.8	1.5	1.8	1.2
RURAL	0.6	0.7	0.8	0.9	0.7
HOV LANES	0.7	0.7	0.7	0.7	0.7

CO EMISSION FACTORS, GMS/MILE

AREA TYPE	FREEWAY	EXPRESS	MIN ART	COLLECT	MAJ ART
CORE	8.7	10.6	35.8	35.8	29.5
CBD	7.2	8.7	29.5	32.2	25.4
OUTLYING CBD	6	8.7	20.3	25.4	16.3
RESIDENT.	5.1	7.2	16.3	20.3	13.1
RURAL	5.1	6	7.2	8.7	6
HOV LANES	6	6	6	6	6

NOX EMISSION FACTORS, GMS/MILE

AREA TYPE	FREEWAY	EXPRESS	MIN ART	COLLECT	MAJ ART
CORE	1.6	1.6	2.1	2.1	1.9
CBD	1.6	1.6	1.9	2	1.8
OUTLYING CBD	1.7	1.6	1.7	1.8	1.6
RESIDENT.	1.8	1.6	1.6	1.7	1.6
RURAL	1.8	1.7	1.6	1.6	1.7
HOV LANES	1.7	1.7	1.7	1.7	1.7

Table 8: Year 2005 and Current On-Road Mobile Source Emissions, Tons per Day

	ROG	CO	NOx
Year 2005	17.1	165.4	34.2
Current	42.0	308.1	36.4

VII. REFERENCES

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APPENDIX I

TECHNICAL REPORTS REGARDING GEOLOGIC AND SEISMIC HAZARDS

Seismic and Geologic Safety
Technical Background Report

Introduction

The following technical report is divided into two separate sections:

- o seismic hazards (earthquakes, faults, liquefaction), including a discussion of the geology of the County and of safety implementation measures; and

- o hazards due to landslides.

This report overlaps much of the descriptive text in Chapter IX (the Safety Element) of this General Plan. In essence, this technical appendix is a longer version of the text in Chapter IX.

I. SEISMIC HAZARDS

Earthquakes

Earthquakes are sudden releases of strain energy stored in the earth's bedrock. Energy can be stored in the earth's crust because the crust is more or less elastic. Under pressure it can be permanently distorted or can store the energy for later release. The release can be slow, in the form of fault creep, or rapid, as an earthquake. Both types of energy release, but especially a large rapid earthquake, can be destructive.

The great majority of earthquakes are not dangerous to life or property either because they occur in sparsely populated areas or because they are small earthquakes which release relatively small amounts of energy. However, where urban areas are located in regions of high seismicity, damaging earthquakes are expectable if not predictable events. Seismic risk is assumed by every occupant and developer in Contra Costa County because the County is within, as part of the Bay Area, an area of high seismicity. For example, the San Francisco Bay Region has been impacted by more than ten severe earthquakes during historic time.

The major effects of earthquakes are ground shaking and ground failure. Severe earthquakes are characteristically accompanied by surface faulting and less commonly by tsunamis and seiches (forms of tidal waves; these terms are described further in the "Flood Hazards" section of this chapter). Flooding may also be triggered by dam or levee failure, or by seismically induced settlement or subsidence. All of the geologic effects are capable of causing property damage and, more importantly, risks to life and safety of persons.

California is located in one of the most seismically active areas of the earth because the state is located on the boundary between the crustal plate underlying the Pacific Ocean and the one forming the American continent. The American plate, as the latter is called, is "drifting" southwesterly relative to the Pacific plate and being forced to override the Pacific plate. The main line of contact between the two plates is the San Andreas fault system. Simply stated, as these plates shove and grind against one another, movement occurs on the San Andreas fault, or a fault parallel to it, and California has earthquakes.

A **fault** is a fracture in the earth's crust along which the rocks on opposite sides have moved relative to each other. All active faults have a high probability of future movement. With regard to planning and development two aspects of fault displacement should be considered: (a) the effects that sudden movement along faults may have on structures built across their traces, and (b) the relatively slow effects of fault creep on structures build across their traces.

Faults vary greatly in their length, age of last displacement, and recurrence interval ("activity"), engineering and geologic characteristics of the fault material and fault zone, and other characteristics. Each fault must be evaluated independently, and then in comparison with similar faults, to place it in a geologic perspective.

Fault displacement involves forces so great that the only means of limiting damage to man-made structures is to avoid the traces of active faults. Any movement beneath a structure, even on the order of an inch or two, could have catastrophic effects on the structure and its service lines. Beginning the instant an earthquake is triggered, a series of events which can have serious consequences for people and property is set into motion. These involve interactions between seismic forces on one hand and natural features and man-made structures on the other.

From the location on the earthquake fault where energy is released, the "focus", energy is radiated outward in the form of vibration waves which are only gradually dissipated. Near the focus, the forces of vibration may be strong enough to physically stress landforms and buildings, while at greater distances the waves can be detected only with instruments.

The shear movement within the earth's crust may continue upward and appear as surface displacement ("ground rupture") along an existing fault or result in creation of new fault breaks. However, earthquakes that originate at great depths within the earth and earthquakes of Richter magnitude less than approximately 6.0 are generally not accompanied by surface faulting. Those earthquakes which are accompanied by surface fault movement pose a special hazard to structures which straddle the active trace. In the vast majority of damaging earthquakes, however, the preponderance of life loss and damage is a result of ground shaking and seismically-triggered ground failure.

Faults are typically not singular breaks in the earth's crust but systems of breaks. Those systems include "fault zones", of paralleling and connecting faults behaving as a single entity, wide belts containing several paralleling and connecting faults along which energy releases may alternate, and linear series of faults that may link and thereby pose the danger of larger magnitude earthquakes.

Energy release events on an active fault may alternate from one trace to another, and movement on a master fault could trigger adjustments on minor, subsidiary faults. Because of these factors, fault traces which intersect or parallel known active faults warrant special consideration during project review.

It has been estimated by the California Division of Mines and Geology that between 1970 and the year 2000, fault displacement losses in California will total $76 million. These losses will occur primarily along active faults in urban centers and in the surrounding suburban communities. Losses from fault displacement are expected to be low compared to losses from earthquake shaking.

Although surface rupture along a fault is dramatic, the physical effects of faulting are highly localized. Not so are the effects of ground shaking which are widespread and cause most earthquake damage. In a great earthquake, major damage from ground shaking can occur over one hundred miles from the source of the earthquake.

Although losses from fault displacement tend to be relatively low, the risks are greatly increased by inappropriate development. For example, fault movement during the 1971 San Fernando earthquake destroyed two hundred houses (average value $25,000) and three commercial buildings (estimated value $200,000) for a total loss of $5.2 million.

Earthquakes are typically described by their strength. The original way of classifying earthquakes is according to how they are felt and what effects are observed by people. A currently-used version of such a system of rating "intensity" is the Modified Mercalli Scale which assigns Roman numerals to earthquakes on a scale of I to XII. An earthquake of "MM.I" intensity probably would not be sensed at all by most people, but one of "M.M.XII" would destroy many buildings and distort the landscape.

Another useful intensity scale, the 6-grade San Francisco intensity scale, is used frequently in the Bay Area. The San Francisco intensity scale is used by the City of San Francisco, by the U.S. Geological Survey, and by the Association of Bay Area Governments (ABAG).

The modern systems measure earthquake size according to the "magnitude" of the energy release and express this amount on a mathematical scale. The Richter scale, which expresses earthquake magnitude on a logarithmic scale, is the best know example of the latter.

Although most people evidently prefer to use the "language" of the instrumentally measured Richter Scale to the Modified Mercalli scale's terminology of human perceptions in describing the strength of earthquakes, few understand the tremendous increases in energy releases which are being registered as readings move up the scale. Each Richter scale unit increase in the scale (say, a change in reading from 1.0 to 2.0) means a ten-fold increase in the size of the wave transmitted by the earthquake or, roughly thirty-seven times the energy released by it. An earthquake measuring 3.0 on the Richter scale would be roughly 1,000 times more powerful than one registering 1.0 (i.e., an increase of two full units on the scale).

Another measurement system is the use of descriptive titles for earthquakes of various strengths. According to this arrangement, earthquakes may be classified according to the descriptive names listed in Table 1.

Earthquake planning and seismic review often use a set of descriptions of predicted earthquake capabilities called "maximum credible earthquake" and "maximum probable earthquake." The maximum credible earthquake is the maximum earthquake that appears capable of occurring. The maximum probable earthquake is the maximum earthquake believed likely to occur during a 100 year interval.

The overall strength of an earthquake is its most important characteristic but not the only characteristic needed for seismic safety planning or construction design. Other important attributes include an earthquake's duration, its related number of significant stress cycles and its accelerations. Structures capable of withstanding more powerful earthquakes can fail in a less severe earthquake of long duration or due to especially high local accelerations.

TABLE 1

Earthquake Size Descriptions

Descriptive Title	Richter Magnitude	Intensity Effects
Minor Earthquake	1 - 3. 9	Only observed instrumentally or felt only near the epicenter. Modified Mercalli Scale, intensity IV or less.
Small Earthquake	4 - 5.9	Surface fault movement is small or does not occur. Felt at distances of up to 20 to 30 miles from epicenter. May cause damage (Modified Mercalli Scale, VII) in small area.
Moderate earthquake	6 - 6.9	Moderate to severe earthquake range. Fault rupture probable; landslides, liquefaction and ground failure triggered by shock waves. Damage extends over a broad area, depending on magnitude and other factors. Maximum intensity ranges from VIII to XII on the Modified Mercalli Scale.
Major earthquake	7 - 7.9	
Great earthquake	8 - 8+	

Source: Compiled by Contra Costa County
Community Development Department

Local Geology

In order to understand the fault system in Contra Costa, where earthquakes are most likley to occur, a brief discussion of the local geology is necessary. Figure 1 illustrates the generalized geology of the County and the accompanying Table 2 summarizes the County's "geologic column" and geologic time scale.

The geology of Contra Costa County is dominated by several northwest trending fault systems which divide the County into large blocks of rock. For example, the Briones Hills are bounded by the Hayward fault on the west and elements of the Franklin-Calaveras fault system on the east. Within a particular block the rock sequence consists of (1) a basement complex of broken and jumbled pre-Tertiary sedimentary, igneous and metamorphic rocks; (2) a section of younger Tertiary sedimentary rocks, more than 35,000 feet thick; and volcanic rocks (flows and tuffs) which locally intertongue with and overlie the sedimentary section; and (3) surficial deposits including stream alluvium, colluvium (slopewash deposits at the foot of steeper hillslopes), slides, alluvial fans, and Bay Plain deposits. The character of each of these categories of rocks are summarized below and in Table 2:

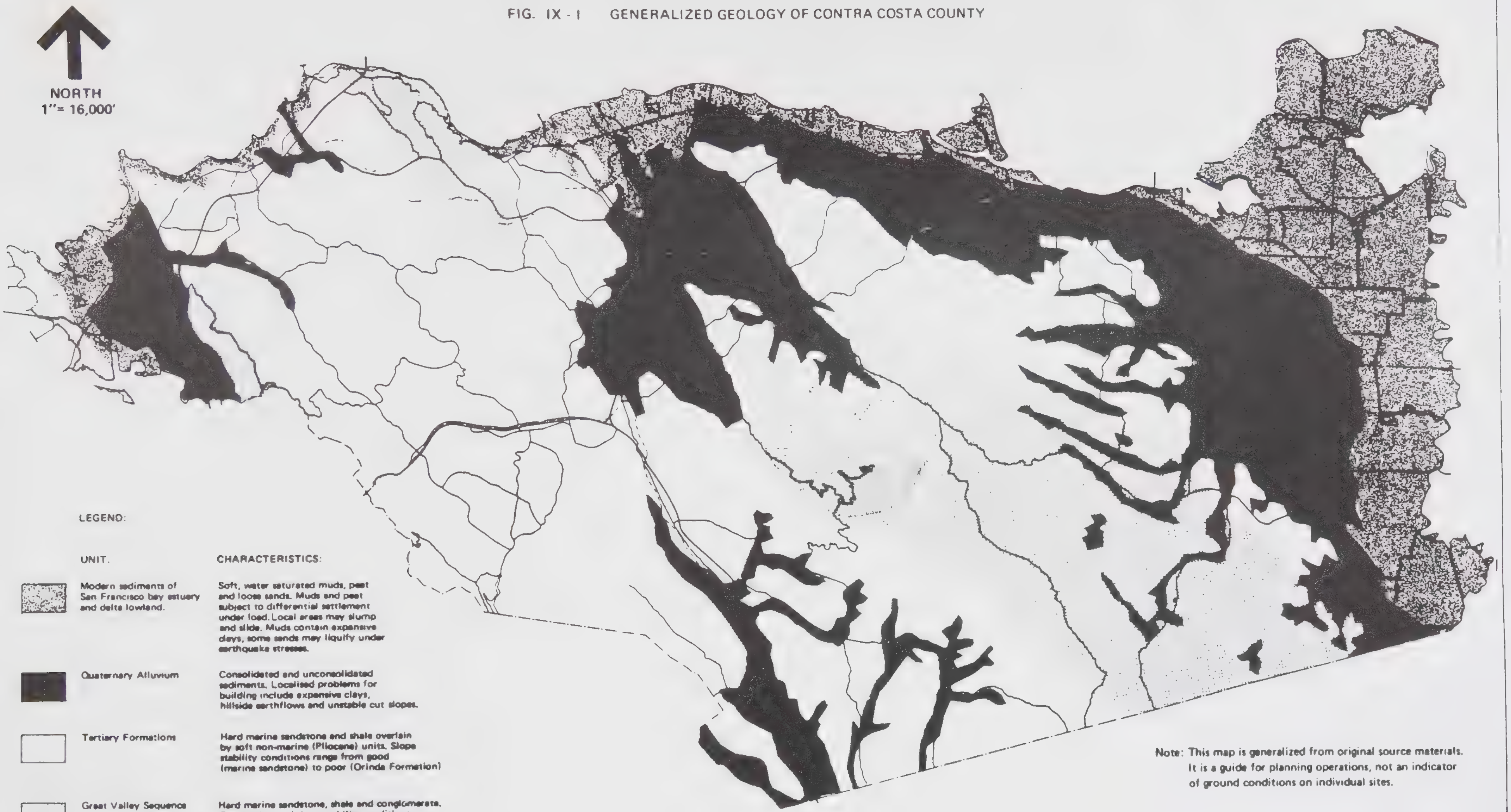
Basement Complex. The oldest bedrock on the surface in the County is the Franciscan formation or assemblage. It is thought that this group originated on the Pacific ocean floor and was "welded" to the western margin of the American continent by plate movement. Subsequently it was uplifted beneath and through younger sedimentary rock to form the backbone of the Diablo Range. Isolated outcrops occur on Mt. Diablo, west of the Hayward fault in the West County, and locally in some other portions of the County.

Befitting its history, the rock strata of this formation are highly distorted and its layers of sedimentary rock are partially metamorphosed through heat and compression. It is intruded by a rock called diabase and other rocks which originated deeper in the crust, and which in turn are altered mostly to serpentine. The relative hardness of some of the rocks in this assemblage gives it good overall behavioral characteristics during earthquakes. But, it is associated with rough topography, and the weathered and sheared materials of some of its steep slopes are susceptible to landsliding.

Cretaceous Sedimentary Rocks. The next oldest bedrock formations in the County belong to the so-called "Great Valley Sequence" or GVS. These are sedimentary rocks laid down under ancient seas. Its strata have been folded, but less extremely broken and sheared than those of the Franciscan assemblage, and the GVS layers are not as highly altered as the Franciscan. Still, the rock tends to be hard and behave well during earthquakes.

The slope stability characteristics of these rocks span a wide range. Erosionally oversteepened slopes, and slopes underlain by sheared, clay-rich, or weathered material are subject to sliding. Great Valley Sequence rocks crop out at higher elevations in the central uplift margin of the Diablo Range and northeast of the Franklin fault in the Briones Hills.

FIG. IX - I GENERALIZED GEOLOGY OF CONTRA COSTA COUNTY



LEGEND:

UNIT.	CHARACTERISTICS:
Modern sediments of San Francisco bay estuary and delta lowland.	Soft, water saturated muds, peat and loose sands. Muds and peat subject to differential settlement under load. Local areas may slump and slide. Muds contain expensive clays, some sands may liquify under earthquake stresses.
Quaternary Alluvium	Consolidated and unconsolidated sediments. Localised problems for building include expensive clays, hillside earthflows and unstable cut slopes.
Tertiary Formations	Hard marine sandstone and shale overlain by soft non-marine (Pliocene) units. Slope stability conditions range from good (marine sandstone) to poor (Orinda Formation)
Great Valley Sequence	Hard marine sandstone, shale and conglomerate. Foundation and slope stabilityconditions good to fair subject to sliding where sheared, fractured or contorted.
Franciscan Formation	Hard sandstone, chert and shale, metamorphic rock and basalt. Forms core of Diablo Range and Briones Hills Foundation support and slope stability in fresh rock good, subject to sliding where sheared.

Note: This map is generalized from original source materials. It is a guide for planning operations, not an indicator of ground conditions on individual sites.

Source: Map compiled from maps from the U.S. Geological Survey and from the California Division of Mines and Geology

GEOLOGIC TIME SCALE
GENERALIZED STRATIGRAPHIC SECTION
AND LITHOLOGIC CHARACTERISTICS

Generalized Stratigraphic Section Geologic Age (Absolute Age*)			General Lithologic Description
Quaternary Holocene & Pleistocene (0-2)		Alluvium	Includes all types of alluvial deposits. In Central Coast Range it is separated from Contra Costa Group by an angular unconformity.
Tertiary Pliocene (2-5)	Contra Costa Group	Bald Peak Basalt Siesta Formation Moraga Formation Orinda Formation	Conglomerate, sandstone, siltstone with minor amounts of limestone and tuff; rapid facies changes. Some basalt and andesite (volcanic) flows. Clastics are semi-consolidated and contain montmorillonite clay. Topographic form highly variable.
Miocene (5-24)	San Pablo Group	Neroly Sandstone Cierbo Sandstone Briones Sandstone	Predominantly marine sandstone with interbeds of shale, siltstone and minor conglomerate. Upper part includes some non-marine beds (e.g. Diablo Formation of Weaver, 1944)
	Monterey Group	Rodeo Shale Hambre Sandstone Tice Shale Claremont shale Sobrante Sandstone	Siliceous shale and fine-grained sandstone. Some zones of rhythmically bedded chert and shale. Bituminous in places. Underlies moderately steep to steep hillsides in Briones Hills.
Oligocene (24-37)		San Ramon Formation	Tuffaceous sandstone, tuff, minor conglomerate and siltstone.
Eocene (37-58)		Markley Formation Nortonville Shale Domengine Sandstone Meganos Formation	Predominately indurated bedrock including shale, siltstone and sandstone. Montmorillonitic clay shales, unstable.
Paleocene (58-66)		Martinez Formation	Marine, Glauconite sandstone and shale. Shale similar to Ecocene.

Generalized Stratigraphic Section Geologic Age (Absolute Age)		General Lithologic Description
Cretaceous (66-144)	Great Valley Sequence	Great Valley Sequence: Massive beds of sandstone alternating with siltstone and shale. Minor conglomerate, limestone and lignite. Complexly folded and faulted. Crops out in Briones Hills and Diablo Range.
Cretaceous-Jurassic (In part contemporaneous with Great Valley Sequence and younger, possibly Tertiary rocks.)	Franciscan Assemblage	Franciscan: Rhythmically bedded graywacke sandstones, shale, siltstones, radiolarian chert, greenstone. Minor amounts of limestone and schist. Partially recrystallized and intruded by serpentine and associated igneous rocks. Strongly deformed.

*Units of absolute age are millions of years before present.

Modified after Radbruch (1969)

NOTE: This table is generalized from original source materials. It is not an indicator of ground conditions on individual sites.

Compiled by Contra Costa County Community Development Department.

Tertiary and Quaternary. The youngest thoroughly consolidated ("hard") bedrock in the County is the group laid down during the geologic age know as the "Tertiary". Most of these strata of largely sedimentary rocks have been folded like their predecessors, but because they have not been as hardened by geologic processes their responses to earthquakes and saturation are much more variable.

Certain of the constituent groups of rocks, such as the late Miocene, Pliocene and younger continental formations, tend to be weak and highly susceptible to landslides. It is expected that these weaker areas would experience numerous instances of ground failure during strong earthquakes. Significantly, many of the foothill areas of the County now coming under development are underlain by Tertiary and Quaternary bedrock.

Volcanic Rocks. Volcanic flows and tuffs as young as Pleistocene age crop out at scattered localities in the central Coast Ranges of California. In Contra Costa County, the Leona rhyolite is exposed in the Berkeley Hills of El Cerrito; basaltic flows and tuffs are present in Orinda Formation equivalents, west of the Moraga fault; and little-folded basaltic flows which are overlain by late Quaternary gravels are exposed in the Diablo Range three miles northwest of Clayton.

Surficial Deposits. These units, which vary widely in their origin and engineering properties, overlie bedrock formations in some areas. In the mountainous portions of the County the surficial deposits include slides, colluvium, alluvial fans, travertine (lime) and upland valley-bottom deposits. In the lower-lying portions of the County the surficial deposits include bay plain sediments and the geologically recent deposits of the San Francisco Bay estuary and Delta lowland.

From the perspective of seismic safety planning the older, coarser, and well-drained materials tend to be stable during earthquakes, while younger, fine-grained and water-saturated deposits tend to be less stable. Colluvium is often marginally stable to unstable. A disproportionate share of landslides originate in colluvium.

Faults

A variety of criteria are used in the literature to establish whether a fault is active. These criteria range from those which are definitive, such as active fault creep or known earthquakes with surface rupture, to those which are more speculative, such as proposed tectonic models which would require that a given fault be active.

In this discussion, faults are grouped according to the criteria which have been used to infer activity. Those with the most definitive criteria are discussed first. The first two categories consist of faults which are known, or inferred from field studies, to have experienced surface displacements during the late Pleistocene or Holocene, which includes approximately the last 10,000 years. Faults in the remaining categories have no reported evidence for geologically recent surface displacements and hence less confidence can be placed in the assessment that they are active.

Faults are seldom single cracks but typically are a series of subparallel or en-echelon breaks that comprise zones. These breaks form networks composed of major and minor faults. A fault having recorded movement, or one which shows evidence of geologically recent displacement (within about the last 10,000 years), is regarded as "active" and is more likely to generate a future earthquake than a fault which shows no signs of recent movement.

Evidence of active faulting may include any of the following: (1) historic earthquake accompanied by surface faulting, (2) tectonic creep, (3) fault offset involving deposits of known or inferred Holocene age, (4) seismic activity, including microtremors, (5) geomorphic and topographic evidence, and (6) regional and area perspectives on Lake Cenozoic, including Holocene, tectonic models.

Faults which have had surface displacement within the Quaternary Period (about the last two or three million years) are considered potentially active. Alignment of earthquake epicenters along a fault trace is an indicator of activity but one which is generally considered to be less compelling than proven Quaternary offset. Similarly, a permeability barrier in Quaternary deposits, a prominent air-photo lineation in Quaternary deposits, a fault trace defined by youthful fault-related topographic features, or a fault trace which closely coincides with the epicentral area of a major historic earthquake are considered to be less certain evidence than proven Quaternary ruptures. These and other criteria have been used to identify faults which may be significant to a project.

Figure 2 shows the earthquake faults that have been mapped in the County and categorizes their recent activity. Further technical information is discussed in the appendix. Table 3 summarizes other available data on inferred active faults affecting Contra Costa County.

Along with the criteria for fault activity, the last time of faulting, based on geologic evidence, is used to access fault activity. The historic record is so short, and earthquakes are so scattered, that they are used only as the surest indicator of fault activity. Other lines of evidence are discussed in the appendix.

In the context of geologic evidence for activity, those faults which have been active during the Holocene period, approximately the last 10,000 years, are considered to be active faults, and those faults which have been active during the Quaternary period, approximately the last 3 million years, are considered to be potentially active faults. This serves to differentiate faults for which sufficient evidence of recent activity has been noted to explicitly include them as known geologic hazards, distinct from those faults for which young displacement is known or suspected, and whose latest activity has not been determined, but may have been within approximately the last 10,000 years.

In addition to faults which have been classified as active or potentially active, there are others whose activity has not been clearly established by presently available information. Some of these faults are shown on Figure 2 and discussed in the appendix. Others remain to be studied.

FIG. IX - 2 MAPPED EARTHQUAKE FAULTS IN CONTRA COSTA COUNTY

EXPLANATION

FAULT MAPPING STATUS

Fault location

Approximate location

Location uncertain

FAULT ACTIVITY CATEGORY

State of California special studies zone

Faults with reported Late Pleistocene displacement but not in a state of California special studies zone

FAULTS WITHOUT EVIDENCE OF LATE PLEISTOCENE OR HOLOCENE SURFACE DISPLACEMENTS

Faults associated with earthquake swarms

Faults inferred active on the basis of scattered small magnitude earthquakes near the trace of the fault

Faults inferred active on the basis of a tectonic model

Notes: This map is generalized from original source materials. It reflects only general purpose seismograph data.

The apparent scattering of the epicenters relative to fault locations is due to instrumentation and measurement problems as well as the dip of the faults and other factors.

Prepared by the Contra Costa County Community Development Department, Contra Costa County, California.

TABLE IX-3

SUMMARY OF AVAILABLE DATA ON INFERRED ACTIVE FAULTS AFFECTING CONTRA COSTA COUNTY

Fault Name	Historic Damaging Earthquakes	Historic Surface Faulting	Known Microseismic Activity	Estimated Maximum Credible Earthquake		Maximum Probable Earthquake	
				Preferred Magnitude	From Literature	Preferred Magnitude	From Literature
San Andreas	1838, 1906	Creep and Surface Rupture	Yes	8½	8.5[1]	8¼	8¼[6]
Hayward	1836, 1868	Creep and Surface Rupture	Yes	7¼	7.0[1] 6.9[2] Range 6-8, most data suggest 7 ± ¼[3] 7.0[5] 5.8 - 7.0[6] 7.6[7]	6½	6 3/4[6]
Calaveras	1861	Surface Rupture	None in Contra Costa County	7¼	7.3[1] 6.7[2] Range 6 - 8, most data suggest 7 ± ¼[3]	6½	6½[6]

Table IX-3 (continued)

Fault Name	Historic Damaging Earthquakes	Historic Surface Faulting	Known Microseismic Activity	Estimated Maximum Credible Earthquake: Preferred Magnitude	Estimated Maximum Credible Earthquake: From Literature	Maximum Probable Earthquake: Preferred Magnitude	Maximum Probable Earthquake: From Literature
Greenville: Clayton Segment	None Known	None Known	No	$6\frac{1}{4}$	6.25 [4][5]	$5\frac{1}{2}$	None
Greenville: Marsh Creek -	1980	Surface Rupture	Yes	$6\frac{1}{2}$	6.5 [4][5]	5 3/4	None
Greenville: Segment					6.3 [7]		
Black Diamond Area	None Known	None Known	Scattered clusters in areas near these faults	$5\frac{1}{2}$	$5\frac{1}{2}$ [4]	Insufficient Data	
Antioch	1889?, 1965	Reported Creep	Yes	$6\frac{1}{2}$	6.6 [1] 5 3/4 [4] 6.5 [6]	5 3/4	$5\frac{1}{2}$ [6]

Table IX-3 (continued)

Fault Name	Historic Damaging Earthquakes	Historic Surface Faulting	Known Microseismic Activity	Estimated Maximum Credible Earthquake		Maximum Probable Earthquake	
				Preferred Magnitude	From Literature	Preferred Magnitude	From Literature
Calaveras (continued)					7¼ (4)(5) 6.5 - 7.2 (6) 7.5 (7)		
Franklin	1898?	None Known	No	6¼	6¼ (5)	Insufficient Data	
Concord	1955	Creep	Yes	6½	6.3 (1) 6.0 (2) Range 6 - 8, most data suggest 7 ± ¼ (3) 6.5 (4)(5) 6.1 - 6.5 (6) 6.4 (7)	5 3/4	5 ½ (6)

The major State legislation regarding earthquake fault zones is the Alquist-Priolo Special Studies Zones Act. The purpose of the Alquist-Priolo Act, as it is commonly known, is to regulate development near active faults so as to mitigate the hazard of surface fault rupture. The law charges the State Geologist with responsibility for preparing maps delineating Special Studies Zones of appropriate width to include all potentially and recently active traces of the San Andreas, Hayward, Calaveras and San Jacinto faults, and it makes provision for the State Geologist to zone other faults where the available evidence was adequate.

The legislation also charges the State Mining and Geology Board with responsibility for formulating policies and criteria affecting all development applications which come under the authority of the Alquist-Priolo act. The enabling legislation specifies that polices and criteria of the Board be embodied in the policies and development regulations of affected local jurisdictions.

The Alquist-Priolo act requires cities and counties to review the fault rupture hazards, based on appropriate geologic reports for new real estate development and most types of new construction, within the Special Studies Zones. Specific policies and criteria to assist local jurisdictions are provided by the State Mining and Geology Board, and geologic guidelines are provided by the State Division of Mines and Geology.

The Alquist-Priolo act does not pertain to existing development, or to the construction of wood-frame, single family homes on existing lots. The act also exempts certain alterations or additions to existing structures. To date the Alquist-Priolo act has been administered as a matter of Board of Supervisor's policy. But, the County has gained experience in administering this law, and it appears feasible and desirable to incorporate these regulations into ordinances.

Recent Seismic Activity

Every time an earthquake occurs, it helps locate active faults and establish probability patterns for projecting future earthquakes. The written history of Contra Costa County indicates that it has experienced frequent earthquakes. Early explorers and settlers in the Bay Area told of earthquakes that must have been felt in Contra Costa County, and the continuous history that has been maintained since the early 1800's clearly shows that the County has been subject to numerous seismic events. To show the pervasiveness of seismic events in this region, one authority has estimated that there have been approximately sixty damaging earthquakes in the Bay Area since 1800. Almost all of these were felt in Contra Costa County, and some did extensive damage here. Some of these originated on faults located within the County and some in other parts of the region.

There is no question that the six major Bay Area earthquakes occurring since 1800 affected the County, nor that at least two of the faults that produced them run through or into the county. These earthquakes and the originating faults include the 1836 and 1868 earthquakes on the Hayward fault, and the 1861 earthquake on the Calaveras fault. Two earthquakes, in 1838 and 1906, originated on the San Andreas fault, west of the county near San Francisco or to the south, and one earthquake (with two major shocks,) which was felt and caused some

damage in the County, occurred in 1872 and was centered north of Contra Costa County in the Vacaville-Winters area of Solano County. A smaller, similar earthquake, centered near Collinsville in Solano on a fault of uncertain identity, occurred in 1889.

Figure 3 shows the locations for epicenters of earthquakes of Richter magnitudes as small as approximately 2.0 (which are unevenly reported because not all of them were recorded by enough stations to be located accurately), and for the period 1934-1980. Some of the differences between epicenter and fault locations are due to inexact methods of locating earthquakes or of mapping faults; other differences reflect the slanting of the fault break through the bedrock; but, still other differences may indicate that lesser earthquakes are taking place on minor faults, or on undiscovered active faults, in the County.

Earthquake Probability and Intensity Estimates

Man does not possess the capability to predict when, where, or how large the next earthquake will be. Two decades of fairly intensive research have not resulted in breakthroughs in earthquake prediction, although it has led to better understanding of pre-earthquake conditions. "Forecasts" may ultimately be possible for some selected, well studied faults or areas.

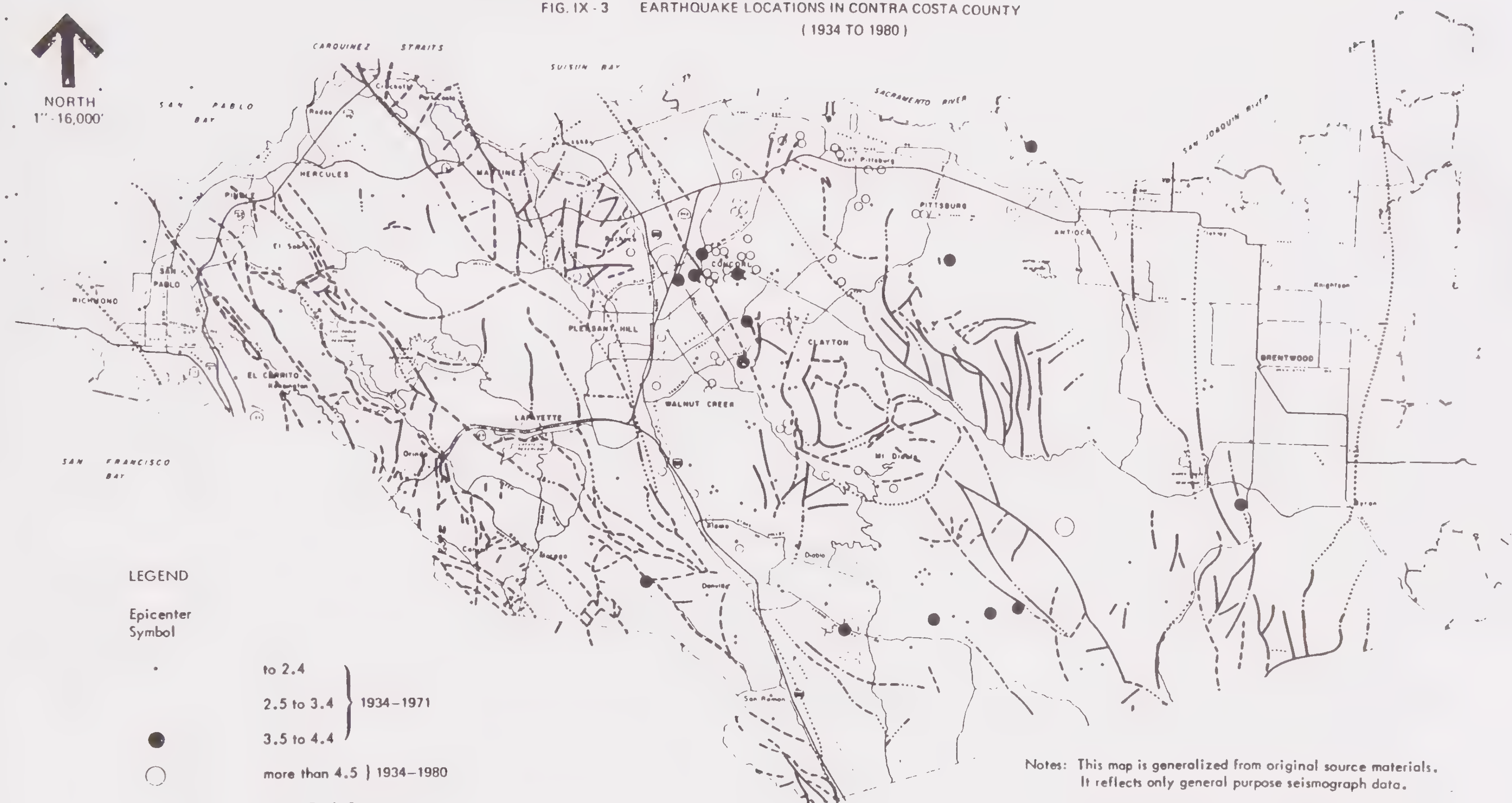
Statistical forecasts presently provide assessments of seismic hazard. More definitive studies require thorough research. Using the available data and information, an earthquake probability estimate has been developed for Contra Costa County and is shown in Table 4.

Table 4 evaluates the likelihood that earthquakes capable of producing damage in Contra Costa County will occur on certain faults during a fifty year period. (Fifty years is a rough average nominal life of a structure.) The forecast shows that a structure built in Contra Costa County is likely to be subjected to a severely damaging earthquake during its useful life, and it shows that the earthquake could originate in several locations.

Knowing that a structure probably will be subject to a damaging earthquake during its useful life, it is only reasonable that it be designed to survive the event, or to at least protect its occupants and functions. To do this, architects and engineers need to have information on earthquake characteristics, such as earthquake accelerations and duration of strong ground shaking. These characteristics have been estimated for selected faults in Table 5. The data in the table may be used as an approximation of parameters prevailing over a large area and as a beginning point for determining the parameters affecting a particular location.

The earthquake parameters are not intended to be used as requirements for public and private projects, but they should be used only by qualified personnel in project background evaluations, and by engineers and architects in their development of structural design criteria. (Prediction of ground motion on a particular building site requires site-specific knowledge of ground conditions and an assessment of the effect of local geology in changing the characteristics of ground motion.)

FIG. IX - 3 EARTHQUAKE LOCATIONS IN CONTRA COSTA COUNTY
(1934 TO 1980)



LEGEND

Epicenter Symbol

Epicenter Symbol	Magnitude	Period
·	to 2.4	1934–1971
	2.5 to 3.4	1934–1971
●	3.5 to 4.4	1934–1971
○	more than 4.5	1934–1980
—·—·—	Major Fault Systems	

Compiled by the Contra Costa County Community Development Department from the University of California (Berkeley) Seismograph Station Records

Notes: This map is generalized from original source materials. It reflects only general purpose seismograph data.

The apparent scattering of the epicenters relative to fault locations is due to instrumentation and measurement problems as well as the dip of the faults and other factors.

TABLE 4

Approximate Probability of Occurrance of Earthquakes on Selected Bay Area Faults (50-Year Period)

Causative Fault	Magnitude	Approximate probability of Occurrence (over a 50-year period)
San Andreas	7.0 - 8.0	Likely
	8.0 - 8.5	Intermediate
Hayward	6.0 - 7.0	Likely
	7.0 - 7.5	Intermediate
Calaveras	6.0 - 7.0	Intermediate
	7.0 - 7.5	Intermediate - Low
Concord	5.0 - 6.0	Likely
	6.0 - 7.0	Intermediate - Low

Definition of Terms:

Likely: Greater than a 50% probability of occurrence.

Intermediate: A 15-50% probability of occurrence.

Low: Less than a 15% probability of occurrence.

Source: Contra Costa County Community Development Department estimates

TABLE IX-5

ESTIMATED MAXIMUM PARAMETERS FOR KNOWN FAULTS AFFECTING CONTRA COSTA COUNTY
(Based on Table IX-3)

Fault	San Andreas	Hayward	Calaveras	Concord	Clayton/Greenville	Antioch
Magnitude(1)	8.25 - 8.5	6.5 - 7.25	6.5 - 7.25	5.75 - 6.5	5.75 - 6.5	5.75 - 6.5
Duration of Strong Shaking(2) (Seconds)	25 -37	18 - 30	18 - 30	7 - 22	7 - 22	7 - 22
Maximum Intensity(3) (M.M.)	IX - XI	VIII - IX	VIII - IX	VII - VIII	VII - VIII	VII - VIII
Peak Horizontal Accelerations on Rock(4)						
Distance from Fault in Miles						
5	.50 - .55	.25 - .50	.25 - .50	.20 - .45	.20 - .45	.20 - .45
10	.45 - .50	.15 - .40	.15 - .40	.15 - .30	.15 - .30	.15 - .30
20	.25 - .30	.10 - .25	.10 - .25	.05 - .15	.05 - .15	.05 - .15
30	.20 - .25	.05 - .20	.05 - .20	.05 - .10	.05 - .10	.05 - .10
40	.15 - .20	.05 - .10	.05 - .10	<.05	<.05	<.05
50	.10 - .15	<.10	<.10	<.05	<.05	<.05

Notes:
(1) Magnitude Estimates from Table IX-3. The first listed magnitude for each fault is the maximum probable earthquake; the second is the maximum credible earthquake. The maximum probable earthquake for the San Andreas Fault is the historic 1906 earthquake.
(2) Bracketed duration for ground motions are 0.5g within 10 miles of the fault. Estimates based on relationships developed by Bolt (1973).
(3) Estimate based on relationships developed by Richter (1958).
(4) Estimates based on relationships developed by Seed and Idriss (1972), Joyner and Boore (1981), Campbell (1981) and Sadigh (1983).

DB/ssz/faltpera.tbl

Most damage from a major earthquake is caused by ground shaking or related consequential ground failures. The 1971 San Fernando earthquake was typical in that roughly ninety-five percent of the dollar damage was attributable to these phenomena, and only five percent to surface faulting. It is predictable that the primary cause of damage in Contra Costa County from either a Great earthquake on the San Andreas fault (or other fault outside the County), or even a moderate earthquake originating on a fault within the County, would be ground shaking and seismically-triggered ground failure.

It has long been recognized that the performance of a structure during an earthquake is closely related to the nature of the ground on which it rests. Historical data has repeatedly demonstrated that structures sited on loose, saturated surficial deposits, in landslide areas and deposits, and on non-engineered fill are subject to severe damage. The damage experience in these areas is in part due to the amplification of earthquake waves in these materials and in part due to ground failure induced by the earthquake waves.

Solid ground or rock tends to dampen ground motion while poorly consolidated and water-saturated materials amplify ground motion. During North America's two Great earthquakes of the Twentieth Century (San Francisco, 1906; Anchorage, Alaska, 1964) it was observed that structures on solid ground near the epicenters frequently fared better than those located on weak materials located some distance away.

It is estimated that ground shaking will account for $21 billion in damage to public and private property in California during the period 1970-2000. Most of the damage and loss of life will occur in zones of high seismic activity, such as the Bay Area, and most of the damage and loss of life will occur in structures which are build on poor ground or which do not comply with the provisions of recently adopted building codes.

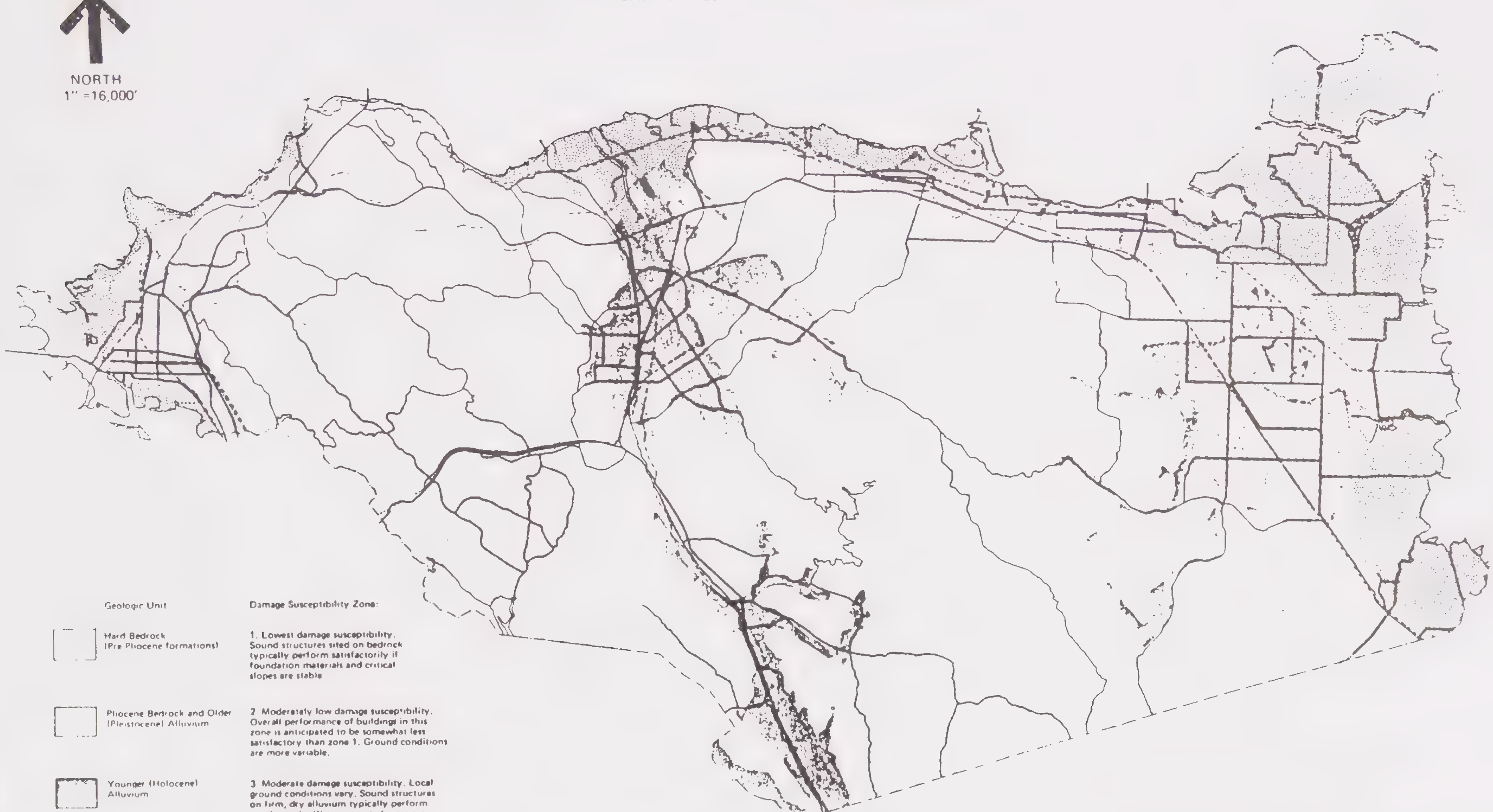
The ways different areas of the County would react to ground shaking have been mapped using approximation methods described in a technical background report included in the appendix. Figure 4 shows the estimated seismic susceptibility (to damage) resulting from this mapping.

As expected, the damage susceptibility of a particular building site is closely related to local ground conditions. Areas situated on hard bedrock (e.g., Briones Hills, Las Trampas Ridge, Diablo Range) may be expected to perform satisfactorily under earthquake conditions, provided that ground materials near the surface do not fail. Areas underlain by weakly consolidated sedimentary rocks (e.g. Pinole Ridge, the Tassajara Area, Alamo) are considered to possess a moderately low to moderate damage susceptibility.

The characteristics of ground motion in alluvial areas will differ somewhat from nearby bedrock areas (e.g., higher amplitudes, longer period, somewhat higher accelerations, etc.), and these differences may be important in the design of sophisticated structures. Areas underlain by firm, dry alluvium are considered to possess a moderate damage susceptibility.

Areas underlain by young bay muds and deposits of the Sacramento-San Joaquin delta are considered to possess the highest damage susceptibility. Most of the County's development and population is located in areas of moderate to moderately low damage susceptibility.

FIG. IX - 4 ESTIMATED SEISMIC GROUND RESPONSE



Geologic Unit	Damage Susceptibility Zone:
Hard Bedrock (Pre Pliocene formations)	1. Lowest damage susceptibility. Sound structures sited on bedrock typically perform satisfactorily if foundation materials and critical slopes are stable
Pliocene Bedrock and Older (Pleistocene) Alluvium	2. Moderately low damage susceptibility. Overall performance of buildings in this zone is anticipated to be somewhat less satisfactory than zone 1. Ground conditions are more variable.
Younger (Holocene) Alluvium	3. Moderate damage susceptibility. Local ground conditions vary. Sound structures on firm, dry alluvium typically perform satisfactorily. Water saturated areas are potentially hazardous.
Modern sediments of San Francisco Bay Estuary and Delta lowlands	4. Highest damage susceptibility. These weak, water saturated deposits possess many adverse engineering characteristics. Earthquake stability poor.

Source: Geologic unit information compiled from U S Geological Survey and California Division of Mines and Geology mapping. Earthquake response interpretation by the Contra Costa Community Development Department

Liquefaction

Liquefaction is a specialized form of ground failure caused by earthquake ground motion. It is a "quicksand" condition occurring in water-saturated, unconsolidated, relatively clay-free sands and silts caused by hydraulic pressure (from ground motion) forcing apart ground material particles and forcing them into quicksand-like liquid suspension. In the process, normally firm, but wet, ground materials are transformed into semi-liquid mixtures.

Catastrophic failures have provided a sobering reminder that liquefaction poses a major threat to the safety of engineered structures. Major landslides, settling and tilting of buildings on level ground, and failure of water retaining structures have all been observed as a result of this type of ground failure. Abundant evidence of slope failure attributable to liquefaction can be seen in photographs taken throughout the Bay Area after the 1906 San Francisco earthquake. It should be emphasized that great earthquakes anywhere in the Bay Area are capable of triggering liquefaction in Contra Costa County.

In many instances it is possible to evaluate the liquefaction potential of granular material rather inexpensively. However, this is not to infer that the consequences of liquefaction, should it occur, are as easily evaluated. Consequences may include effects as minor as slight settlement, or as major as the loss of a reservoir or a Delta levee.

Historically, ground failure in its various forms, including liquefaction, has been a problem in areas of continually wet, unconsolidated geologic units. In Contra Costa County the areas which are most susceptible to ground failure include the geologically young sediments of the San Francisco Bay estuary, including the Delta lowlands.

Within the area of continually wet unconsolidated deposits (Zone IV on Figure 4), the degree of seismic risk is closely related to local ground conditions. A site underlain by a great thickness of potentially unstable material (soft, compressive muds and loose, clay-free sands, etc.) is extremely hazardous. It should be recognized that such a site has a very limited development potential. Conversely, a site underlain by a minimum thickness of soft muds possesses a much better development potential. Utilizing existing knowledge of foundation engineering, such a site could be made suitable for a variety of land uses.

Liquefaction presents the potential for the most serious consequences in the Delta. Several pre-development studies have confirmed that a high potential for liquefaction exists below levees and proposed developments. This potential presents the possibility that several failures can occur simultaneously on a single levee, possibly preventing access for repairs. Flooding of the protected island would then be impossible to prevent and make emergency relief and later repair very difficult.

Layers of ground material that are liquefied during an earthquake undermine the support of both natural landforms and man-made structures. Bluffs and ridges of unconsolidated material may slump under their own weight. Buildings and structures may sink and lean. Often used photographs taken after the 1964 Niigata, Japan earthquake show a group of multi-story apartment buildings leaning acutely or lying on their sides. These buildings remained intact, but this is not always the case when foundation support is diminished. Unfilled pipelines may rise to the surface on account of their buoyancy.

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Woodward-Clyde Consultants

January 17, 1986
16613A/2000

Contra Costa County Community Development Department
Administration Building North Wing
Pine and Escobar Streets
P.O. Box 951
Martinez, CA 94553

Attention: Mr. Todd Nelson

Subject: Revisions of Portions of
Contra Costa County Seismic Safety Element

Gentlemen:

Please find enclosed several copies of revisions of portions of the Contra Costa County Seismic Safety Element. This work included revision of portions covering liquefaction, and active faults and seismicity, in accordance with our contract 31853-00-16236. We have previously submitted copies of the revised 1:24,000 scale liquefaction potential Administration Maps, and the originals for the enclosed Figures 1, 2 and 3 (Mapped Faults, Earthquake Locations, and Estimated Liquefaction Potential).

Enclosed are the text describing the results of our evaluation of active faulting and seismicity, and liquefaction potential in the County. Also enclosed are Table I summarizing data on active faults affecting the county, and Table II estimating maximum earthquake parameters for known faults affecting the county. Also enclosed is a print of Contra Costa County at a scale of 1:24,000 on which we have located significant faults.

The liquefaction evaluation was performed by Lelio Mejia, Senior Project Engineer, and the active faulting and seismicity evaluation was performed by Ross Wagner, Senior Staff Geologist. We have enjoyed working with you on this interesting project. Please contact us if you need additional consultation, or if you have any questions.

Sincerely,

WOODWARD-CLYDE CONSULTANTS

Albert P. Ridley
Senior Project Geologist

APR/ggw
2258r

REVISION OF PORTIONS OF CONTRA COSTA COUNTY SEISMIC SAFETY ELEMENT

INTRODUCTION

A considerable amount of new information has become available regarding the seismic hazards in Contra Costa County since the Seismic Safety Element of the Contra Costa County General Plan was adopted in 1975. Therefore, the Contra Costa County Community Development Department has directed the revision of portions of the Seismic Safety Element to include much of this new information. The revision effort was directed towards two portions of the Seismic Safety Element: Active Faulting and Seismicity, and Liquefaction Potential. The scope of work and the results of these efforts are described below.

ACTIVE FAULTING AND SEISMICITY

SCOPE OF WORK

This effort consisted of a review of existing literature to identify faults which have been inferred to be active and an attempt to describe some of the characteristics of these faults. Fault characteristics include geomorphic indicators, historic seismicity, the presence of surface rupture or creep, and maximum credible and maximum probable earthquake. The results of this work include: a revised fault map (figure 1), a revised seismicity map (Figure 2), a revised administrative map of faults at a scale of 1:24,000, and a summary of fault activity criteria and estimated earthquake magnitudes (Table I).

A variety of criteria are used in the literature to establish whether a fault is active. These criteria range from those which are definitive, such as active creep or major earthquakes with surface rupture, to those which are more speculative, such as proposed tectonic models which would require that a given fault be active. In the following discussion, faults are grouped according to the criteria which have been used to infer activity. Those with the most definitive criteria are discussed first. The first two categories consist of faults which are known, or inferred from field studies to have experienced surface displacements during the late Pleistocene or Holocene (approximately the last 10,000 years). Faults in the remaining categories have no reported evidence for geologically recent surface displacements and hence less confidence can be placed in the assessment that they are active.

Maximum credible and maximum probable earthquakes are defined by the California Division of Mines and Geology (CDMG Note 43, 1975) as follows:

Maximum Credible Earthquake

"The maximum credible earthquake is the maximum earthquake that appears capable of occurring under the presently known tectonic framework. It is a rational and believable event that is in accord with all known geologic and seismologic facts. In determining the maximum credible earthquake, little regard is given to its probability of occurrence, except that its likelihood of occurring is great enough to be of concern. It is conceivable that the maximum credible earthquake might be approached more frequently in one geologic environment than in another."

Maximum Probable Earthquake

"The maximum probable earthquake is the maximum earthquake that is likely to occur during a 100-year interval. It is to be regarded as a probable occurrence, not as an assured event that will occur at a specific time."

Procedures for estimating maximum earthquake magnitudes generally relate some measurable characteristic of a fault to the maximum earthquake which could occur on the fault. Rupture length and rupture area, for example, are commonly used to evaluate the maximum magnitude on a given fault. Unless otherwise stated, earthquake magnitudes presented in this report are expressed in the M_s magnitude scale. All earthquake magnitudes presented in the literature have been recalculated using equations presented by Schwartz & others (1984) and the same fault parameters as used in the cited literature. As a result, some of the magnitudes shown in Table I, in some cases, differ slightly from those shown in the cited literature.

<u>Faults Which Have Produced Historic Earthquakes, Exhibit Creep, And Are Included In State California Special Studies Zone</u>

<u>Hayward Fault</u>. A part of the Hayward fault (Figure 1) lies at the western edge of Contra Costa County in the cities of Richmond and San Pablo. Major earthquakes, one with surface rupture, occurred on the Hayward fault in 1836 and 1868 (Toppazada and Park 1982). Creep has been identified at a number of locations along the fault (Hirschfield, 1982; Radbruch 1968), and the fault is well defined by a zone of microseismicity (Ellsworth and others 1982). Geodetic measurements show a slip rate of 7 $\pm$1 mm/year on the Hayward fault (Prescott and others 1981). Most of the surface trace of the fault is sufficiently well defined that it has been placed in a special studies zone by the State of California (1982). It should be noted that in the reach of the Hayward fault in the Berkeley Hills in Contra Costa County the surface expression is disrupted in many places by massive landslides, and that fault traces may not be reliable indicators, everywhere, of future locations for surface rupture.

The maximum credible earthquake for the Hayward fault has been estimated by several authors and their results are shown in Table I. Two of these estimates (Slemmons & Chung 1982, Shedlock & others 1980) give

maximum values in excess of 7.5. The estimates of Shedlock and others (1980) are based on the relation between rupture length and magnitude and the assumption of a 100% rupture on a 190 km long fault that includes the Hayward fault and the most active, southern part of the Calaveras Fault. This rupture would extend from the southern end of the Calaveras fault near Hollister, northward to Calaveras Reservoir, where it would break across the East Bay Hills, join the southern end of the Hayward fault, and extend northwesterly to San Pablo Bay. The connection between the Calaveras and Hayward faults is probably made because: 1) near Calaveras Reservoir, the two are linked by a thin linear belt of microseismicity (Ellsworth and others 1982) and, 2) geodetic studies show that part of the slip on the southern part of the Calaveras fault is transferred to the Hayward fault in the same area (Prescott and others 1981).

The geodetic and seismic data make it impossible to disprove that a rupture could connect the two faults, however the absence of evidence for surface faulting in the area (Hart and others 1981) suggests that it is unlikely that the two faults would rupture as a unit. The estimates of maximum earthquake magnitudes based on this interpretation are, therefore, probably too high.

Slemmons & Chung (1982) defined the Hayward fault zone as including the southern end of the Calaveras fault to the vicinity of Calaveras Reservoir, the Hayward fault along the east side of San Francisco Bay and the Rodgers Creek and Maacama faults to the north of San Francisco Bay. They then consider this entire 280 kilometer long feature as a single throughgoing structure for purposes of earthquake magnitude estimates. For the reasons discussed above these fault length estimates are probably too long. However, since Slemmons & Chung (1982) estimate a rupture length of only 19% of this total length, their magnitude estimate (using the length to magnitude relationship) is actually lower than that of Shedlock and others (1980). Slemmons and Chung (1982) also estimate the maximum credible earthquake on the Hayward fault using a variety of other methods, some of which are independent of the total length of the fault.

Applying these different approaches to the Hayward fault they conclude that the range of maximum earthquake magnitudes is 6 to 8 with most data suggesting magnitudes of 7 ± ¼.

Those magnitudes reported by Slemmons & Chung (1982) which relate maximum magnitude to fault length are probably too high due to an excessive estimate of fault length, however none of these methods give earthquake magnitudes which exceed 7.1. This, when taken in conjunction with the other approaches used by Slemmons & Chung (1982), suggests that 7¼ is a conservative value for the maximum credible earthquake for the Hayward fault. A value of 6 1/2 has been selected for the maximum probable earthquake.

Calaveras Fault. The Calaveras fault lies in the south central part of the county along the western side of the San Ramon Valley (Figure 1). The northward extention of the fault and its relationship to other faults are both unclear because the literature contains a variety of structural interpretations and contradictory fault names.

With respect to fault names, Lawson (1914) and Ham (1952) used the name Franklin fault for the northern projection of the Calaveras fault in the vicinity of Tice Valley and Alamo. Saul (1973) and Dibblee (1980e), on the other hand, referred to the fault in this area as the Calaveras fault. Because Lawson (1914) originally used the name Franklin fault to a point south of Tice Valley we will also use that name in that area.

The boundary between the two faults is chosen here as the north end of the special studies zone defined on the Calaveras fault in the San Ramon Valley. This boundary is in the southern most part of the town of Danville, approximately 2 miles north of the town of San Ramon.

The Calaveras fault experienced an earthquake with surface rupture in the southern part of Contra Costa County in 1861. The magnitude of that earthquake has been variously estimated at 5.6 (Toppozada & others, 1981)

to 6 (Wesson & others 1975). The 1861 surface rupture may have extended into the southern end of what is here called the Franklin fault. Moderate-sized earthquakes with surface rupture have occurred on the fault to the south of the county. No creep is currently known to be occurring on the Calaveras fault within Contra Costa County, although creep does occur on the southern reach of the fault.

South of Calaveras Reservoir the fault is well defined by a thin linear belt of microseismicity, however, north of the reservoir, in Alameda and Contra Costa Counties, there is no direct association between the fault and microseismicity (Ellsworth and others, 1982)

In southern Contra Costa County the geomorphic expression is sufficiently well developed that it has been placed within a Special Studies Zone by the State of California. The Special Studies Zone is terminated at a point approximately 2 miles north of San Ramon on the east flank of Las Trampas Ridge (Earl Hart, 1981).

Most estimates of the maximum credible earthquake magnitude for the Calaveras fault cluster around 7.0 (Table I). Shedlock and others (1980), however, estimate a maximum magnitude of 7.5. This interpretation is based on the assumption of a rupture length equal to 100% of the total length of the Calaveras fault between its southern end near Hollister and its northern end near San Ramon. Because most earthquakes rupture less than 100% of the total fault length (North American examples range from 2 to 75 percent of total fault length, (Wentworth and others, 1969)) this estimate is probably too high.

Slemmons & Chung (1982) define the Calaveras Fault zone as consisting of the Calaveras fault from a point near Hollister northward to the vicinity of Danville, the Concord fault from Danville to Suisun Bay and the Green Valley fault north of Suisun Bay. For purposes of seismic assessment they assume these three structures function as a single 280 kilometer long fault. The precise connection between the Calaveras

and Concord faults is not clear, however, both Weaver & Hill (1979) and LaViolette & Wigginton (1983) have suggested that at least some of the right lateral displacement on the Calaveras fault is being transferred to the Concord fault in the vicinity of Danville and that the Danville earthquake swarms of 1970 and 1976 are a manifestation of this transfer of displacement. Well-documented stepover distances on strike-slip faults have reached a maximum of 3 kilometers (Bonilla, 1979). Because the proposed stepover from the Concord to the Calaveras faults takes place across a distance of approximately 7 kilometers, it seems unlikely that a single rupture would join these faults. As a result, those estimates of Slemmons & Chung (1982) which relate maximum credible earthquake to fault length are probably too high. Slemmons & Chung (1982) also used methods which are independent of fault length. When all of the data was considered, they concluded that the maximum credible earthquake for the Calaveras fault could range from 6-8, but that most of the data suggest a value of 7 $\pm$ 1/4.

Because some of the estimates of Slemmons & Chung (1982) are probably too high, a value of 7-1/4 is considered a conservative value for the maximum credible earthquake for the Calaveras fault. A value of 6-1/2 has been selected for the maximum probable earthquake.

Greenville Fault--Marsh Creek-Greenville Segment. The Greenville fault (Figure 1) is a major tectonic element in Central Contra Costa County which extends from Livermore Valley northwesterly to Suisun Bay. Because of earlier uncertainties concerning the continuity of faulting, parts of the Greenville fault have, in older literature, been given different names. In particular, the part of the Greenville fault to the north of Mt. Diablo has been called the Clayton fault, however more recent work (see for example Earth Science Associates, 1982) has shown the fault to be a continuous feature. Earth Science associates (1982) divided the Greenville fault into three segments based on geomorphic expression and stepovers along the strike of the fault. The Arroyo Mocho Segment extends from the southeast corner of Livermore Valley southeasterly for

at least 28 kilometers. The Marsh Creek-Greenville Segment extends from the southeast corner of Livermore Valley northwesterly to a point southeast of the summit of Mt. Diablo, while the Clayton segment extends along the east side of Clayton Valley northward from the north end of the Marsh Creek-Greenville segment. The Clayton segment is discussed on Page 16.

Two moderate earthquakes (magnitudes reported were 5.4 to 5.8 and 5.2 to 5.8) occurred on the Marsh Creek-Greenville segment in January of 1980 (Bolt and others, 1981, and Bonilla and others 1980) (Figure 2). These earthquakes were associated with surface rupture (Bonilla and others, 1980).

Abundant microseismicity occurred along the fault trace after the earthquakes of 1980 (see for example Ellsworth and others, 1982). The State of California has zoned this segment of the Greenville fault as a Special Studies Zone (1982).

Two somewhat different estimates have been made for the maximum credible earthquake on the Marsh Creek-Greenville Segment. Earth Science Associates (1982) believes the Marsh Creek Segment will rupture independently from the rest of the Greenville fault and estimates a maximum credible earthquake of 6.5. This is based on a rupture of approximately 2/3 of the total segment length.

Shedlock and others (1980) suggest a maximum credible earthquake of 6.9. Their interpretation is based on a 100% rupture of a 50 km long fault. It is difficult to evaluate Shedlock and others (1980) because of inconsistencies between fault lengths shown on figures and those discussed in the text. The Greenville fault as shown in Figure 1 and 2 of Shedlock and others (1980) extends from the central part of the Marsh Creek-Greenville Segment of Earth Science Associates (1982) southward into the Arroyo Mocho Segment. Figure 1 (Shedlock and others, 1980) shows the fault to be approximately 40 km long and Figure 2 shows it to

be approximately 30 km long. There is no discussion in the text of Shedlock and others (1980) of how the 50 km length was obtained.

Because Earth Science Associates (1982) reports differing geomorphic expression between the Arroyo Mocho and the south end of the Marsh Creek-Greenville Segments, and because Hart (1981a) does not recognize evidence for recent faulting to the north of the north end of the Marsh Creek-Greenville Segment of Earth Science Associates (1982), the suggestion that this is a rupture segment is accepted and a maximum credible earthquake of 6-1/2 is assigned to the Marsh Creek-Greenville Segment. A maximum probable earthquake of 5-3/4 has been selected for the Marsh Creek-Greenville Segment.

The Concord Fault. The Concord fault (Figure 1) is a northwest striking feature which lies along the east side of Ygnacio Valley extending from south of Ygnacio Valley Road through downtown Concord and into Suisun Bay (Sharp, 1973; State of California 1974a, 1974b, 1974c). The southern end of the fault is located in the hills to the west and southwest of Mt. Diablo near the southeastern part of the town of Walnut Creek. The fault can be traced northward into Suisun Bay where it lies approximately along strike of the Green Valley fault - a fault located outside of Contra Costa County, but one which is identified as being active (Frizzell and Brown, 1976). The fault was probably the source of the magnitude 5.4 earthquake of October 1955 (Sharp, 1973). Creep has been reported along the Concord fault by both Sharp (1973) and Galehouse and others (1982), and the central part of the fault is well defined by a belt of microseismicity (Ellsworth and others 1982).

The surface expression of the fault is sufficiently well developed that it has been placed in a Special Studies Zone by the State of California (1974a, 1974b, 1974c).

Estimates of the maximum credible earthquake magnitude for the Concord fault range from 6 to 8, however, except for the analysis of

Slemmons & Chung (1982, see Table 1), they cluster in the 6.0 to 6.5 range. The results of Slemmons & Chung (1982) differ from the other analyses for a number of reasons. First, because they have treated the Calaveras, Concord, and Green Valley faults as a single through going feature, and hence, their calculations are based on a greater total length than if these faults are analyzed separately. As has been discussed in the assessment of the Calaveras fault, it seems very unlikely that the Calaveras and Concord faults would be joined by a single rupture because of the large lateral step between the two faults. In addition, the proposal that the Green Valley and Concord faults could be connected by a throughgoing rupture is one which other studies have disagreed with. Earth Science Associates (1982) suggested that the Green Valley and Concord faults would rupture independently of one another because of an 11 degree difference in the strike of the faults, an approximate 1 mile wide right step between the north end of the Concord fault and the south end of the Green Valley fault, and a change in the sense of vertical displacement.

Secondly, Slemmons & Chung (1982) used parameters which change along the strike of the structures. For example, relationships have been developed between slip rate and magnitude, and these data suggest that the Calaveras fault zone would produce maximum credible earthquake magnitude of from 6.7 to 7.8. However, the slip rate is higher on the Calaveras fault than on the Concord fault, and hence the maximum credible earthquake inferred on the Concord fault would be lower than that inferred for the Calaveras fault zone as a whole.

Excluding the values of Slemmons & Chung (1982), estimates of maximum credible earthquake range from 6.0 to 6.5, and based on these interpretations a magnitude of 6 1/2 has been selected as the preferred value for the maximum credible earthquake on the Concord fault (Table I). A maximum probable earthquake of 5-3/4 has been selected for the Concord fault.

<u>Antioch Fault</u>. The Antioch fault is a northwest striking structure which runs through the city of Antioch in the eastern part of Contra Costa County (Figure 1). The fault extends approximately 3 miles south of Antioch where it joins the Davis Fault (Burke and Helley, 1973). No major earthquakes have been unequivocally associated with the Antioch fault, although it may have been the source of the 1889 Collinsville earthquake which reached a Modified Mercalli Intensity of VII at Antioch and Collinsville in Solano County (Coffman and others, 1981). This earthquake had an estimated magnitude of 6.0 and surface rupture may have occurred in Antioch (Toppozada & others 1981).

In September of 1965 an earthquake swarm occurred just southwest of Antioch. The epicenters of these earthquakes occupied a north-northwest trending zone which lies slightly more than 2 kilometers west of the mapped trace of the Antioch fault.

There is uncertainty as to whether the Antioch fault is currently experiencing creep, but the majority of data currently available suggest that creep is occurring. Burke and Helley (1973) interpreted damage to cultural features in the Antioch region as resulting from creep on the fault. Galehouse (1982) performed geodetic surveys across the Antioch fault, and concluded that episodic creep might be occurring, but that it is probable that nontectonic movements influenced the results of the geodetic survey. Knuepfer (1977) stated that the magnitude of offsets observed on curbs and streets was generally within the realm of concrete expansion and contraction cracks. However, he identified 5 locations where this explanation did not appear to be sufficient (Knuepfer, 1977 p. 29).

On the basis of relationships exposed in a cut bank, Earth Science Associates (1982) concluded that "the age of the last offset (on the Antioch Fault) must be Post-Pliocene, and is most likely Holocene." Similar relationships also occur outside the state's special studies zone near the intersection of Lone Tree Way and East Tregallis Road (Todd

Nelson, Personal Communication, 1985). The surface expression of the fault was interpreted to be sufficiently well developed that the State of California (1976a, 1976b) has placed it in a special studies zone.

Three estimates of maximum credible earthquake magnitude have been made for the Antioch fault (Table I). Two of these, 6.6 by Wesson & others (1975) and 6.5 by Woodward-Clyde Consultants (1984), are consistent with one another, but the third, 5 3/4 by Earth Science Associates, (1983), differs substantially. According to Earth Science Associates (1983, p 66) the magnitude value of 5 3/4 was obtained by applying the curves of Slemmons (1977) to a 12 km long rupture length. A review of Slemmons curves (1977, p 91) shows that a 12 km long rupture length on a strike-slip fault (curve E on Slemmons, 1977, Figure 27) would produce an earthquake with a magnitude of approximately 6.1. If the regression equations of Schwartz & others (1984) are applied to a 12-km-long rupture the magnitude is approximately 6.2. A conservative value of 6 1/2 has been selected as the preferred value for the maximum credible earthquake on the Antioch fault (Table I). The preferred value for the maximum probable earthquake has been chosen as 5-3/4.

Faults Located Outside Of Contra Costa County Which Have Produced Major Historic Earthquakes, Exhibit Creep, and Are Included In A State of California Special Studies Zone

San Andreas Fault. The San Andreas fault is located outside of Contra Costs County, however, because it is capable of producing a very large earthquake and strong ground motions within the County, it will be considered briefly here.

The fault is a northwest striking feature which extends from Mexico to northern California. In the Bay Area it is located on the San Francisco Peninsula, offshore of the Golden Gate Bridge and in Marin County between Bolinas Lagoon and Tomales Bay. At its closest approach, it lies 15-16 miles southwest of the City of Richmond.

The San Andreas was the source of the Richter magnitude 8-1/4 earthquake of 1906, and it displays creep and microseismicity in areas south of the San Francisco Bay area. During the 1906 earthquake, approximately 20 feet (6 meters) of right lateral strike slip displacement was observed in Marin County. Wesson & others (1975) estimate a maximum Richter magnitude of 8-1/2 for the San Andreas Fault. The preferred value for the maximum probable earthquake has been chosen as 8-1/4.

Faults With Reported Late Quaternary or Holocene Displacements But Without Sufficient Geomophic Expression To Be Included In a State Of California Special Studies Zone.

Franklin Fault. As has been previously discussed, existing maps show the Calaveras and Franklin faults to be a continuous structure which extends along the west side of the San Ramon Valley (Figure 1). In this discussion the location at which the name changes from Calaveras to Franklin Fault has been chosen to occur at the north end of the State of California special studies zone on the east flank of Las Trampas Ridge approximately two miles north of the town of San Ramon.

The location of the Franklin fault north of Alamo is uncertain. Although differing in detail, regional mapping by Lawson (1914), Ham (1952), Saul (1973), and Dibblee (1980d, 1980e) indicate that it can be traced along the east flank of Las Trampas Ridge, and the east side of Tice Valley. Ridley and others (1982), however, trenched the mapped trace of the fault just east of Tice Valley and reported that no bedrock fault with strike-slip characteristics exists at that location. Although clear evidence for strike-slip displacement is lacking, there are relatively complex relationship between the Franklin and other faults in this area and it is possible that deformation is distributed through a relatively wide zone and that some of the faults within this zone show primarily dip slip movements. Studies by Woodward-Clyde Consultants (1979a, 1979b) identified a dip slip fault along the east side of Tice Valley.

To the north of Highway 24, Lawson (1914) shows the Franklin fault to be a continuous feature from the Walnut Creek area to the Carquinez Straits. Saul (1973) shows what he called the Calaveras fault to extend as a continuous feature to the north edge of his study area in Pleasant Hill. Dibblee (1980b, 1980e), shows the Franklin fault (he calls it the Calaveras fault) joining the Southampton fault in Walnut Creek, and shows the Southampton fault extending into the Carquinez Straits near Martinez. Dibblee (1980b, 1980c, 1980e) shows the Franklin fault as extending from the Carquinez Straits near Crockett southeastward to Pleasant Hill. At this point, he ends the Franklin fault and leaves an approximately 350 meter wide (1000 foot) gap between it and the adjacent Southampton fault.

It is not possible, from information available at this time, to resolve the conflict between the various interpretations of the location of the Franklin fault. For purposes of this analysis, the conservative assumption will be made that the Franklin and Calaveras faults are a continuous bedrock feature which extends along the east flank of Las Trampas ridge through the vicinity of Tice Valley and northwesterly to the Carquinez Straits.

Quaternary surface activity on the Franklin fault has been evaluated in trenches excavated within a few feet of the main trace of the fault in the vicinity of Franklin Canyon. Exposures in the trenches show multiple displacements in the past 35,000 to 40,000 years and some recurrent offset of colluvium estimated to be on the order of from as young as 8,000 to 12,000 to as old as about 20,000 years old (Earth Science Associates, 1983).

An evaluation by the California Division of Mines and Geology showed that there was not sufficient geomorphic expression for the fault to be included in a special studies zone (State of California, 1974c).

Whether all of the Franklin fault has experienced Holocene or Late Quaternary movement is difficult to evaluate with the data currently

available. At its northern end trenches excavated by Earth Science Associates (1983) show late Pleistocene and possibly Holocene displacement. To the south, through Pleasant Hill, Walnut Creek and the San Ramon Valley, there is no clearly documented evidence for late Quarternary displacements. For example, several studies done in Tice Valley have indicated that no late Quaternary displacement has occurred on the fault at that location. (Woodward-Clyde Consultants 1978, 1979a, 1979b).

At its southern end, where it joins the special studies zone located at the north end of the Calaveras fault, it might be expected to show Holocene displacements. However, some authors (Weaver & Hill 1979, and LaViolette & Wigginton 1983) have suggested that at least some of the right lateral displacement on the Calaveras fault is being transferred eastward to the Concord fault. This would suggest that no displacement, or a reduced rate of displacement, is occurring along the Franklin fault, located to the north of this zone of transfer. Because of the uncertainties in connections between the Franklin and other faults and because of the relative lack of data on Quaternary history along much of its length, in this report the southern part of the fault has been included in the fault activity category "inferred active on the basis of a tectonic model". The southern end of the area included in this category is placed at the northern end of the Special Studies zone just north of San Ramon. The northern boundary is placed in Pleasant Hill at the point where the trace of the Franklin fault passes from alluvium (on the south) to bedrock (on the north).

No major earthquakes can be unequivocally associated with the Franklin fault, although it is possible that the 1898 Mare Island earthquake, having an estimated magnitude of 6.2 (Toppozada & others 1981), may have occurred on this fault (Table I). No historic surface faulting or creep have been reported on the fault and it is not associated with microseismicity (Ellsworth & others 1982).

Earth Science Associates (1983) estimated a maximum credible earthquake magnitude of 6-1/4 for the Franklin Fault (Table I). Considering the available data, this appears to be a reasonable estimate for the preferred magnitude of the maximum credible earthquake. Because there is insufficient data upon which to make an assessment, no maximum probable earthquake has been assigned to the Franklin fault.

Greenville Fault--Clayton Segment. The Clayton Segment is on the northern projection of the Greenville fault, a structure which produced earthquakes with surface rupture in January of 1980. As defined by Earth Science Associates (1982) the Clayton segment extends from a point southeast of the summit of Mt. Diablo northwesterly along the eastern edge of Clayton Valley to the vicinity of Port Chicago.

No major earthquakes are known to have occurred on this fault, nor does it display surface creep or a strong pattern of microseismicity, although scattered microseismicity in the area of the fault could be attributed to it (Personal Communication, Pat Gomez, Beta Associates, 1985). A number of consultant reports developed for proposed subdivisions have reported surface displacements interpreted to be Quaternary or Holocene in age near the south end of the fault (Woodward-Lundgren and Associates, 1974), however, the geomorphic expression of the Clayton segment is not sufficiently strong to include it in a Special Studies Zone (State of California 1974a, 1974b).

As shown in Table I a preferred magnitude of 6 1/4 has been selected for the maximum credible earthquake on the Clayton segment of the Greenville fault. This is primarily based upon the estimates of Earth Science Associates (1982, 1983). In addition, an estimate of 5-1/2 has been selected for the maximum probable earthquake.

Black Diamond Area Faults. The Black Diamond area faults consist of five north-south to northwest striking faults (Figure 1). These structures include the Keller Ridge, Oil Canyon, Stewartville, and Long Canyon

faults, as well as an unnamed fault which lies between the Long Canyon and Stewartville fault (see Brabb and others 1971, Dibblee 1980a, and ESA, 1982). Names and precise locations of these faults differ depending on which of the above references is used. The terminology and fault locations used by Brabb and others (1971) are used here.

No notable historic earthquakes are known to have occurred on these faults, nor are there any reports of surface rupture, and they are not included in a special studies zone (State of California 1976b). Scattered, relatively low density clusters of microseismicity occur in the area of these faults (Ellsworth & others 1982), but no clear spacial relations with the faults are evident (Figure 2). Earth Science Associates (1982) excavated trenches across the northern end of the Stewartville fault and an unnamed fault just east of it. They observed deformation of soil and colluvium in these trenches and concluded that: "there remains the possibility that the observed relationships (displacement of soils) are the result of minor folding and/or local landslidings. In general, however, the evidence indicates that the Stewartville Fault and related north-trending faults in the area are minor old tectonic features with possible minor late Quaternary movement. They are therefore, considered to be potentially seismogenic."

On this basis these faults are considered, in this study, to have experienced Quaternary movements, but the level of confidence in this interpretation is lower than for other faults having reported Quaternary displacements. Based upon work performed by Earth Science Associates (1982) it appears reasonable to estimate a maximum credible earthquake of about 5 1/2 for these faults (Table I). Because there is insufficient data, no maximum probable earthquake has been assigned to these faults.

<u>Faults Inferred To Be Possibly Active Because Of Association With Earthquake Swarms</u>

<u>Pinole Fault</u>. The Pinole fault is a northwest striking feature which extends from the City of Pinole southeastward at least as far as Orinda (Figure 1). No known significant earthquakes have occurred on this fault

nor is any creep known to be occurring. The State of California originally included the northern end of the Pinole fault in a special studies zone, but later work by geologists of the California Division of Mines and Geology resulted in its being removed from the zone (Bedrossian, 1980).

Microseismic activity may have occurred on the Pinole fault in 1977. In January of that year a small swarm of earthquakes occurred in the Briones Hills. The epicenters of these earthquakes plot as a northwest trending belt coincident with the trace of the Pinole fault (Figure 2) (Bolt and Others, 1977).

An analysis of focal mechanisms by Bolt and Others (1977) indicates a northwest striking southwest dipping right lateral strike slip fault was responsible for the 1977 Briones Hills swarm. On the basis of the southwest dip of the focal plane, Bolt suggests that the swarm may have occurred on faults located to the east of the Pinole fault. However, because of the close spacial relationship between the surface trace of the Pinole Fault and the epicenters of the 1977 swarm, the Pinole Fault is tentatively interpreted in this analysis to be the source of the swarm. No estimates of maximum earthquake magnitudes have been made for this fault.

<u>Faults Inferred To Be Active Because Of Scattered Microseismicity In The Vicinity Of The Surface Trace Of The Fault</u>

Earth Science Associates (1982) and the California Department of Water Resources (1978) have inferred several faults to be potentially seismogenic on the basis of scattered microearthquakes having occurred in the vicinity of the surface trace of those faults. Faults included in this category are the Riggs Canyon and Morgan Territory faults, located just southeast of Mt. Diablo; and the Brentwood, Vaqueros, and Kellogg faults, located in the low hills between Antioch and Byron. None of these faults are known to have experienced significant earthquakes or surface rupture, and none are known to display creep. None of these

faults are included in State of California Special Studies Zones (see Figure 1). No estimates have been made of possible maximum earthquakes on these faults.

The Davis fault (Figure 1) is also included in the category; however the data concerning this fault are complex and subject to various interpretations. The Davis Fault is a north-northwest striking structure which lies to the east of Antioch and extends southward to the vicinity of Kellogg Creek. Burke and Helley (1973) show the Antioch fault to splay northwesterly from the Davis fault in the vicinity of Antioch and they report 15-cm-high scarps in alluvium on the Davis fault south of its intersection with the Antioch fault. The State of California (1976) has included this same part of the Davis fault in a special studies zone.

The California Department of Water resources (1978) has reported on trenches excavated across the fault within the special studies zone. One of these trenches crossed the scarp reported by Burke and Helley (1973). It showed an unbroken sequence of soils estimated to the 50,000 to 100,000 years old which overlies a possibly faulted 200,000 year old soil. It was further reported that none of the trenches excavated south of this locality showed any signs of displacement in soils estimated to be 50,000 to 70,000 years old.

The Department of Water Resources (1978) also reported that microseismicity was occurring along the Davis fault and concluded, "The present pattern of activity is one of small earthquakes -- apparently so small they have not broken the ground surface within the last 50,000 to 100,000 years." Earth Science Associates (1982) also concluded that the Davis fault is potentially seismogenic on the basis of scattered microseismicity occurring in the vicinity of the trace of the fault.

Contradictory interpretations by Burke and Helley (1973), the State of California (1976), and the Department of Water Resources (1978) do not unequivocally establish whether the Davis fault has experienced

Quaternary displacement. In the absence of any clearly defined Quaternary displacements in trenches excavated by the Department of Water Resources (1978) the fault is included in the Category "Active on the basis of Scattered Epicenters occurring in the vicinity of the trace of the fault." By placing the fault in this category the part of the fault just south of its intersection with the Antioch fault is not considered to show late Quaternary displacement, even though it is included within a special studies zone. Insufficient data exists to estimate possible earthquake magnitudes on these faults.

Faults Inferred To Be Active On The Basis Of Tectonic Models

Mt. Diablo Fault. The Mt. Diablo fault (Figure 1), located along the south side of Mt. Diablo, is inferred by Earth Science Associates (1982) to be at least seismogenic if not capable of fault ground rupture. This inference is based on the interpretation that the Mt. Diablo fault acts as a zone of transfer of right lateral displacement from the Greenville fault to the Concord fault.

Southampton Fault. The Southampton fault (Figure 1) is a northwest striking structure which diverges from the Franklin fault a few miles northwest of Walnut Creek. No earthquakes are known to have occurred on this fault, nor has creep surface rupture been reported, and the fault is not associated with microseismicity (Ellsworth & others 1982).

Earth Science Associates (1983) has excavated trenches across the Southampton fault just north of Highway 4. They concluded that the relationships observed in these trenches "are permissive of a bedrock fault located at depth." In addition, the trenches showed an unbroken sequence of soils and colluvium overlying the possible fault trace. ESA concluded that "although the age of these surficial materials is unknown, similar materials elsewhere in the study region are at least several thousand years old (Earth Science Associates, 1983, p 24). Dibble & Darrow (reported in Earth Science Associates, 1983) suggested that right

lateral displacement on the Southampton fault has produced the northward bend of the Sacramento River in the Carquinez Straits. Earth Sciences Associates (1983, pp 23 and 51) disagree with this interpretation because the fault has little in the way of topographic expression that is suggestive of late Quaternary displacement, and trenches revealed unbroken surficial deposits overlying the trace of the fault.

Earth Science Associates (1983) concluded that, although there was no evidence for late Quaternary movement, the fact that the Southampton fault lies between two active faults (the Concord and Franklin), and along the projected trend of the Calaveras fault, it should be considered to have some seismic potential.

In addition to the Mt. Diablo and Southhampton Faults, the southern part of the Franklin Fault (Figure 1) is considered to be potentially active on the basis of a tectonic model. This interpretation has been previously discussed in the sections on the Calaveras and Franklin Faults. Insufficient data are available to make estimates of possible maximum earthquake magnitudes on the Mt. Diablo and Southampton Faults.

LIQUEFACTION POTENTIAL

SCOPE OF WORK

This effort included revisions of the liquefaction potential map (Figure 3) and revisions of the administrative maps of liquefaction potential (scale 1:24,000) used by the County staff for planning purposes. These revisions are based on existing soil data from geotechnical reports in County and Woodward-Clyde Consultants files. In addition, new advances in the evaluation of liquefaction potential and in the understanding of liquefaction phenomena are incorporated.

Boring data were evaluated using currently accepted methods and criteria for evaluation of liquefaction potential. Based on the results of these evaluations, the administrative maps were revised as the data permitted. The administrative maps were used to revise the liquefaction potential map in the Seismic Safety Element.

LIQUEFACTION

Background

Liquefaction is a natural phenomenon during which a loose saturated granular soil undergoes a loss in strength and develops a condition similar to a viscous liquid. In this state the soil is in a "quicksand" condition and can flow under gravity as a heavy liquid. During earthquakes, liquefaction may result in ground failure with potentially severe damaging effects to natural and man-made structures.

Several phenomena are commonly observed as a result of liquefaction. These include the formation of sand boils, lateral ground spreading, and

mud flows. Additionally, as the soil settles from its liquefied state, settlements of the ground surface result. If the soil deposit is dry (and therefore cannot liquefy), vibratory shaking from earthquakes may still produce compaction and accompanying settlement.

For liquefaction to occur, a vibrational disturbance of the soil, such as that produced by earthquake shaking, is usually required. If this disturbance results in a tendency for densification, and the soil is saturated and the pore water is unable to drain, excess pore water pressures will develop. This increase in pore water pressures will result in a decrease in effective stresses (intergranular friction) within the soil and a corresponding loss of strength. Depending on the duration and intensity of the disturbance, the effective stresses may be reduced to very small values resulting in a total strength loss and a liquefied state.

Liquefaction cannot occur in deposits of dense sands or clays of low sensitivity. Soils prone to liquefaction include loose to medium dense sands and silts occurring below the water table. Liquefaction of coarse gravels is rare because they are highly permeable and they dissipate excess pore water pressures rapidly.

The disturbance causing soil liquefaction can be static or dynamic. An example of a static disturbance would be an increase in external loading of a soil deposit by a structure or slope. Earthquake shaking is typical of a dynamic disturbance. In this case, the tendency for densification of certain soils results from soil strains caused by the earthquake stresses. These stresses are produced by the propagation of seismic waves through the soil deposit.

The loss of strength of liquefied soil results in a decrease of its bearing capacity and accompanying foundation failure of structures, instability of slopes, and lateral spreading of level ground. The increase in pore water pressures within the soil results in upward flow

of water, which causes the formation of sand boils and perhaps a rise in the water table. Evidence of this phenomenon is the floating of embedded structures, such as tanks and basements, which has been observed during past earthquakes. As the pore water pressures dissipate, the sand densifies. This densification causes ground surface and structural settlements.

Evaluation Of Liquefaction Potential During Earthquakes

General Approach. As previously discussed, the tendency for densification of a soil deposit during earthquake shaking results from the soil strains induced by shear stresses produced by the propagation of seismic waves. If the magnitude of the shear stresses is insufficient to produce significant strains within the soil, or the duration of strong shaking is relatively short, the seismic disturbance may not produce liquefaction. However, some increase in pore pressures and corresponding settlement may result.

The general approach for evaluation of liquefaction potential is to compare the cyclic shear stresses produced by the design earthquake with the resistance to liquefaction of a soil deposit. Because earthquakes produce irregular cyclic shear stresses during the period of shaking, the effects of an earthquake are typically represented by an equivalent number of uniform cycles of an average stress. Similarly, the resistance to liquefaction of a soil specimen is typically measured in the laboratory by repeatedly applying uniform cycles of shear stress. The liquefaction potential is evaluated by comparing the magnitude of the earthquake shear stresses with the magnitude of the stresses required to produce liquefaction of the soil in the laboratory in the same number of cycles.

Methods For Estimating Earthquake Stresses And Liquefaction Resistance. The methods used to estimate the shear stresses induced by an earthquake involve an evaluation of the dynamic response of the soil deposit during the earthquake. The dynamic response can be estimated using sophisticated numerical techniques for the analysis of seismic wave

propagation or simple methods based on estimates of peak ground surface acceleration.

Methods for evaluating the liquefaction resistance of soils range from complex laboratory testing programs to simplified comparisons with the performance of soil deposits during past earthquakes. These comparisons are typically based on some in-situ measure of the engineering characteristics of the soil deposit such as the standard penetration test blow count or the shear wave velocity.

Design Earthquake Criteria. To evaluate the liquefaction potential of a soil deposit it is necessary to determine the shear stresses produced by the design earthquake at depth. The criteria for selection of the design earthquake is typically to minimize the risk to structures and human life. This study is based on the same criteria adopted by Contra Costa County in the existing Seismic Safety Element. To take into account the varying degree of seismic risk posed by earthquakes of different magnitude, the County has adopted two design earthquakes as follows:

(1) A great earthquake on the Bay Area segment of the San Andreas fault which would have a surface wave magnitude of approximately 8.0 and would be comparable to the 1906 San Francisco earthquake.

(2) A moderate earthquake on an active fault in Contra Costa County. This event would have a Richter magnitude of approximately 6.5 and would be comparable to the 1971 San Fernando earthquake.

The great earthquake on the San Andreas fault is expected to produce peak accelerations on rock in Contra Costa County ranging between 0.15g and 0.4g. The moderate earthquake on a nearby fault is expected to produce maximum peak acceleration on rock of about .35g. These levels of peak ground acceleration on rock were used in the assessment of liquefaction potential.

The peak acceleration at the surface of a soil deposit usually differs from that expected on a rock outcrop. This difference is due to amplification or reduction of the intensity of earthquake shaking caused by the propagation of seismic waves through the soil deposits. The amplification or reduction of ground motion depends on several factors including the intensity of earthquake shaking, the engineering characteristics of the materials involved, and the depth of the soil deposit.

The effects of local soil conditions on peak ground surface acceleration can be estimated using the results of studies by Seed and Idriss, (1982). These studies indicate that at the intensity of shaking corresponding to a peak acceleration on rock of 0.35g, deep soil deposits and soil deposits containing soft to medium stiff clay and sand are expected to experience lower peak ground surface accelerations. The reduction is such that the expected ground surface acceleration is 0.3g for deep soil deposits and 0.25g for soil deposits containing soft to medium stiff clay and sand.

<u>General Seed-Idriss Procedure</u>. The liquefaction potential for the Contra Costa Seismic Safety Element was assessed using the simplified procedure proposed by Seed and Idriss, (1982). This procedure is based on an evaluation of the cyclic shear stresses produced by the design earthquake in terms of: 1) the peak acceleration at the ground surface, 2) the total soil stress at the particular depth of interest, and 3) a reduction factor with depth. This reduction factor accounts for the variation of ground acceleration with depth.

Using this procedure, the ratio between earthquake shear stresses and effective vertical stress at a particular depth is given by:

$$T/S' = 0.65\ (A/g)\ (S/S')\ R_d$$

where T = the average induced earthquake shear stress; S' = effective vertical stress at depth; S = total vertical stress at depth; A = peak ground surface acceleration; g = acceleration of gravity; and R_d = depth reduction factor.

The cyclic resistance of the soil is a function of the soil type, the corrected standard penetration test blow count, and the earthquake magnitude. The earthquake magnitude defines the number of stress cycles applied to the soil. The corrected standard penetration test blow count can be computed as

$$N1 = (C)(N)$$

where N1 = corrected standard penetration resistance, C = correction factor which depends on the effective stress prior to earthquake shaking and N = standard penetration test blow count. The cyclic resistance to liquefaction depends on the soil type and increases with increasing fines content and plasticity of the soil. Highly plastic clay soils are not susceptible to liquefaction.

Based on the soil type and its corrected penetration resistance the cyclic resistance to liquefaction can be obtained from the relationships published by Seed and Idriss, (1982) for different soil types and earthquake magnitudes. The factor of safety against liquefaction at any particular depth within a soil deposit can be computed by dividing the cyclic resistance by the stress ratio induced by the earthquake.

<u>Liquefaction Criteria</u>. In the evaluation of liquefaction potential for this study the same criteria previously used by the County for the existing Seismic Safety Element was adopted. Thus, sites where liquefaction potential was evaluated were classified into three categories as follows:

(1) Sites with a high potential for liquefaction. These sites contain extensive deposits of soils likely to liquefy during a moderate magnitude earthquake on a nearby fault and during a great earthquake on the San Andreas fault.

(2) Sites with a moderate liquefaction potential. These are sites with occasional lenses of sediment having a marginal liquefaction potential depending on earthquake size, duration, and sediment properties such as grain size and degree of sorting.

(3) Sites with a low potential for liquefaction. These are sites with soils unlikely to liquefy in the event of a moderate magnitude earthquake on a nearby fault or during a great earthquake on the San Andreas fault.

Soils with a high potential for liquefaction during an earthquake were defined as those having a factor of safety less than 0.9 against liquefaction. Soils unlikely to liquefy were required to have a factor of safety greater than 1.4. The liquefaction potential was judged marginal for soils having a factor of safety been 0.9 and 1.4.

These factors of safety were selected after studying the data used in establishing the conditions presented by Seed and Idries (1982). The selected factors of safety account for scatter in the data. The data shows that in some cases liquefaction did not occur even though the factor of safety was below 1.0 and as low as 0.9. The data also incorporates cases when liquefaction occurred even though the factor of safety was higher than 1.0 and as high as 1.4.

<u>Data Analysis</u>. For the assessment of liquefaction potential throughout the County the sites for which geotechnical reports were available were located on copies of the administrative maps. Information regarding: 1) the soil conditions 2) the depth to groundwater at the site, 3) average blow counts for potentially liquefiable soil units, and 4) the

average depth below the ground surface to these soil units, was obtained from the geotechnical reports. Judgement was used to correct the data where it was obtained using procedures different than the standard. Based on the data, a factor of safety against liquefaction during the design earthquakes was computed for each soil unit and the site was classified with respect to liquefaction potential depending on the extent of the liquefiable materials.

Using engineering judgment, an allowance was made for seasonal variations in the water table and the quality of the data in the geotechnical reports. The results of the analyses were incorporated into the administrative maps. Where sufficient data were available, the existing contours on the administrative maps were revised. During this revision, available geological data regarding the distribution of potentially liquefiable soil units throughout the County were used.

Discussion

The results of this study are intended to be used for planning purposes only. When using the results of this study, some of its limitations should be kept in mind.

(1) The study is based on limited data. The data consisted of about 600 geotechnical reports throughout the county. A significant number of these reports were investigations with insufficient data to permit an assessment of liquefaction potential. Although liquefaction can occur at depths approaching 50 feet, a significant number of the geotechnical reports contain data to a depth of only 20 feet.

(2) Soils are known to vary markedly within short distances. The evaluation of liquefaction potential for this study is accurate at the specific location of the available borings. Extrapolation was required to draw contours of liquefaction potential based on geological information regarding stratigraphy of soil units.

(3) The present evaluation of liquefaction potential was made for specific design earthquakes. Variations in earthquake magnitude and distance may result in different outcomes than those predicted. Similarly, variations in the water table and soil conditions from those conditions that existed at the time of exploration may result in markedly different behavior.

In spite of these limitations, it is believed that the results of this study are valuable for County planning. The revised administrative maps can be used to locate areas of high risk due to liquefaction potential. Where areas of moderate to high liquefaction potential are encountered, additional investigation regarding site specific liquefaction potential may be required. Depending on these specific evaluations the need for mitigating measures can be assessed.

Ground Motion Parameters

For engineering applications, earthquake ground motions are typically characterized by parameters such as peak acceleration, peak velocity, peak displacement, duration of strong motion and response spectra for structural design. In this study the same parameters previously adopted by the County have been used. These parameters are: 1) duration of strong motion, 2) maximum or epicentral intensity, and 3) peak ground acceleration. They are summarized in Table II.

The duration of strong shaking corresponds to duration of ground motions above an acceleration level of 0.05 g. These durations were obtained using the correlations by Bolt, (1974) between earthquake magnitude and duration of strong motion. The maximum or epicentral intensity was obtained using the correlation with earthquake magnitude published by Richter, (1958).

The peak ground surface accelerations on rock shown on Table II are mean expected values. That is, values which are expected to be exceeded on 50 out of every 100 occurrences. They were obtained using

relationships between mean peak acceleration and distance from the fault for different earthquake magnitudes as published by Seed and Idriss (1982), Joyner and Boore (1981), Campbell (1981), and Sadigh (1983).

The above ground motion parameters are intended only as a guide to estimate expected or likely values of maximum ground motions.

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TABLE I SUMMARY OF AVAILABLE DATA ON INFERRED ACTIVE FAULTS AFFECTING CONTRA COSTA COUNTY

Fault Name	Historic Damaging Earthquakes	Historic Surface Faulting	Known Microseismic Activity	Estimated Maximum Credible Earthquake		Maximum Probable Earthquake	
				Preferred Magnitude	From Literature	Preferred Magnitude	From Literature
San Andreas	1838, 1906	Creep and Surface Rupture	Yes	8 1/2	8.5(1)	8 1/4	8 1/4(6)
Hayward	1836, 1868	Creep and Surface Rupture	Yes	7 1/4	7.0(1) 6.9(2) "Range 6-8, Most data suggest 7 ± 1/4"(3) 7.0(5) 6.8 - 7.0(6) 7.6(7)	6 1/2	6 3/4(6)
Calaveras	1861	Surface Rupture	None in Contra Costa County	7 1/4	7.3(1) 6.7(2) "Range 6 - 8, Most data suggest 7 ± 1/4"(3) 7 1/4(4)(5) 6.5 - 7.2(6) 7.5(7)	6 1/2	6 1/2(6)
Franklin	1898?	None Known	No	6 1/4	6 1/4(5)	Insufficient Data	
Concord	1955	Creep	Yes	6 1/2	6.3(1) 6.0 "Range 6 8, Most data suggest 7 ± 1/4"(3) 6.5(4)(5) [illegible] - 6.[illegible](6) 6.4(7)	5 3/4	5 1/2(6)

TABLE 1 SUMMARY OF AVAILABLE DATA ON INFERRED ACTIVE FAULTS AFFECTING CONTRA COSTA COUNTY (concluded)

Fault Name	Historic Damaging Earthquakes	Historic Surface Faulting	Known Microseismic Activity	Estimated Maximum Credible Earthquake		Maximum Probable Earthquake	
				Preferred Magnitude	From Literature	Preferred Magnitude	From Literature
Greenville Clayton Segment	None Known	None Known	No	6 1/4	6.25(4)(5)	5 1/2	None
Greenville - Marsh Creek Segment	1980	Surface Rupture	Yes	6 1/2	6.5(4)(5)	5 3/4	None
Greenville - Segment		unknown			6.9(7)		
Black Diamond Area	None Known	None Known	Scattered clusters in areas near these faults	5 1/2	5 1/2(4)	Insufficient Data	
Antioch	1889?, 1965	Reported Creep	Yes	6 1/2	6.6(1) 5 3/4(4) 6.5(6)	5 3/4	5 1/2(6)

References:
(1) Wesson and Others (1975)
(2) Herd (1979)
(3) Slemmons and Chung (1982)
(4) Earth Science Associates (1982)
(5) Earth Science Associates (1983)
(6) Woodward Clyde Consultants (1984)
(7) Shedlock and Others (1980)

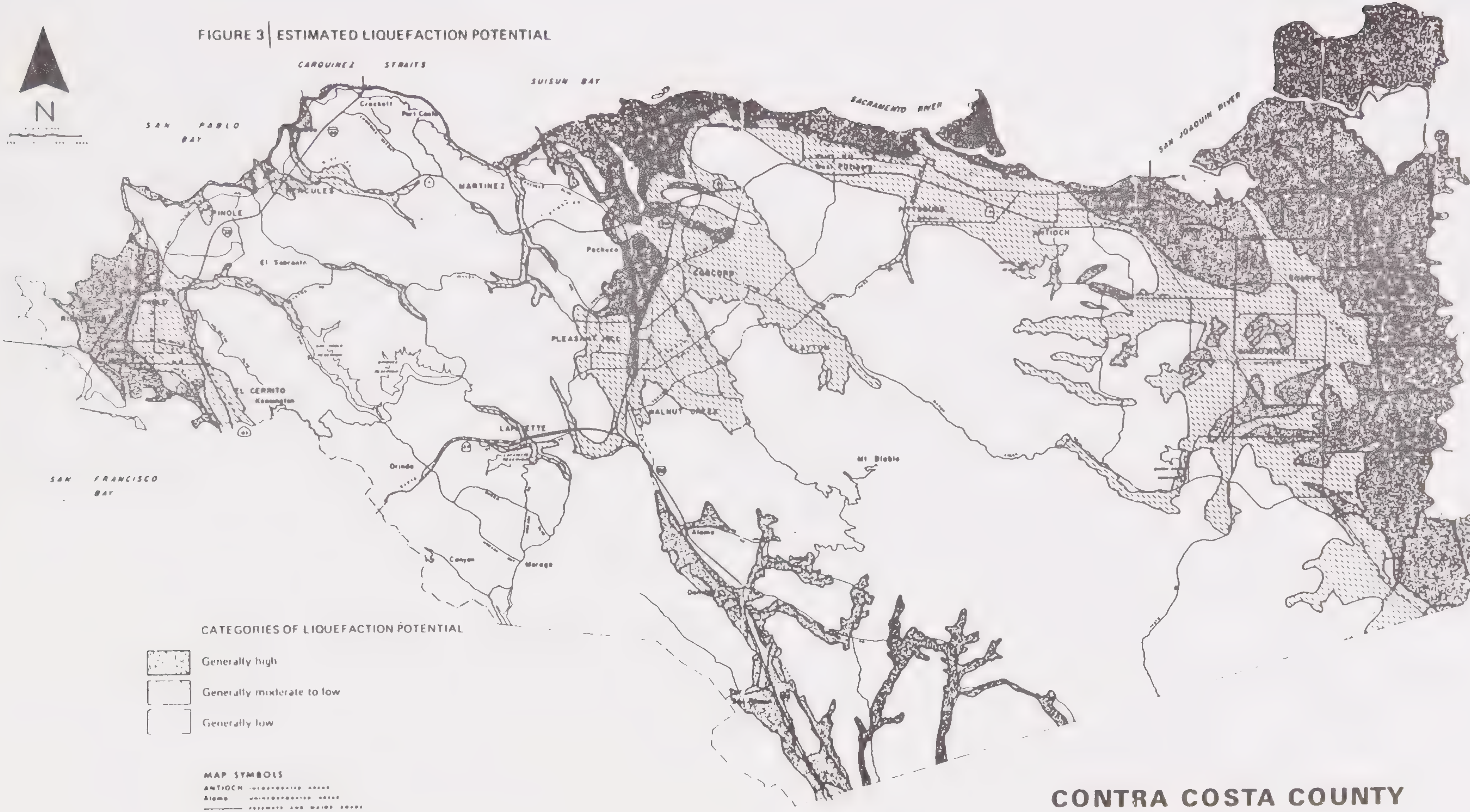
(8) The maximum credible earthquake is the maximum earthquake that appears capable of occurring under the presently known tectonic framework. It is a rational and believable event that is in accord with all known geologic and seismologic facts. In determining the maximum credible earthquake, little regard is given to its probability of occurrence, except that its likelihood of occurring is great enough to be of concern. It is conceivable that the maximum credible earthquake might be approached more frequently in one geologic environment that in another. (CDMG Note 43, 1975).
(9) The maximum probable earthquake is the maximum earthquake that is likely to occur during a 100 year interval. It is to be regarded as a probable occurrence, not as an assured event that will occur at a specific time. (CDMG Note 43, 1975).

Table 11 ESTIMATED MAXIMUM PARAMETERS FOR KNOWN FAULTS AFFECTING CONTRA COSTA COUNTY

Fault	San Andreas	Hayward	Calaveras	Concord	Clayton/Greenville	Antioch
Magnitude[1]	7.0 - 8.25	6.5 - 7.25	6.5 - 7.25	5.75 - 6.5	5.5 - 6.25	5.5 - 6.25
Duration of Strong Shaking [2] (Seconds)	25 - 37	18 - 30	18 - 30	8 - 22	7 - 18	7 - 18
Maximum Intensity [3] (M.M.)	IX - XI	VIII - IX	VIII - IX	VII - VIII	VII - VIII	VII - VIII
Peak Horizontal Accelerations on Rock (9)[4]						
Distance from Fault in Miles						
5	.35 - .55	.25 - .50	.25 - .50	.15 - .45	.15 - .40	.15 - .40
10	.25 - .45	.15 - .40	.15 - .40	.10 - .30	.10 - .25	.10 - .25
20	.15 - .25	.10 - .25	.10 - .25	.05 - .15	.05 - .15	.05 - .15
30	.10 - .25	.05 - .20	.05 - .20	.05 - .10	.05 - .10	.05 - .10
40	.05 - .20	.05 - .10	.05 - .10	<.05	<.05	<.05
50	.05 - .15	<.10	<.10	<.05	<.05	<.05

Notes: (1) Magnitude Estimates from Table 1
(2) Bracheted duration for ground motions are 0.05g within 10 miles of the fault. Estimates based on conditions by Bolt (1973).
(3) Estimate based on conditions by Richter (1958)
(4) Estimates based on relationships by Seed and Idriss (1982), Joyner and Boore (1981), Campbell (1981) and Sadigh (1983).

FIGURE 3 | ESTIMATED LIQUEFACTION POTENTIAL



CATEGORIES OF LIQUEFACTION POTENTIAL

Generally high

Generally moderate to low

Generally low

MAP SYMBOLS

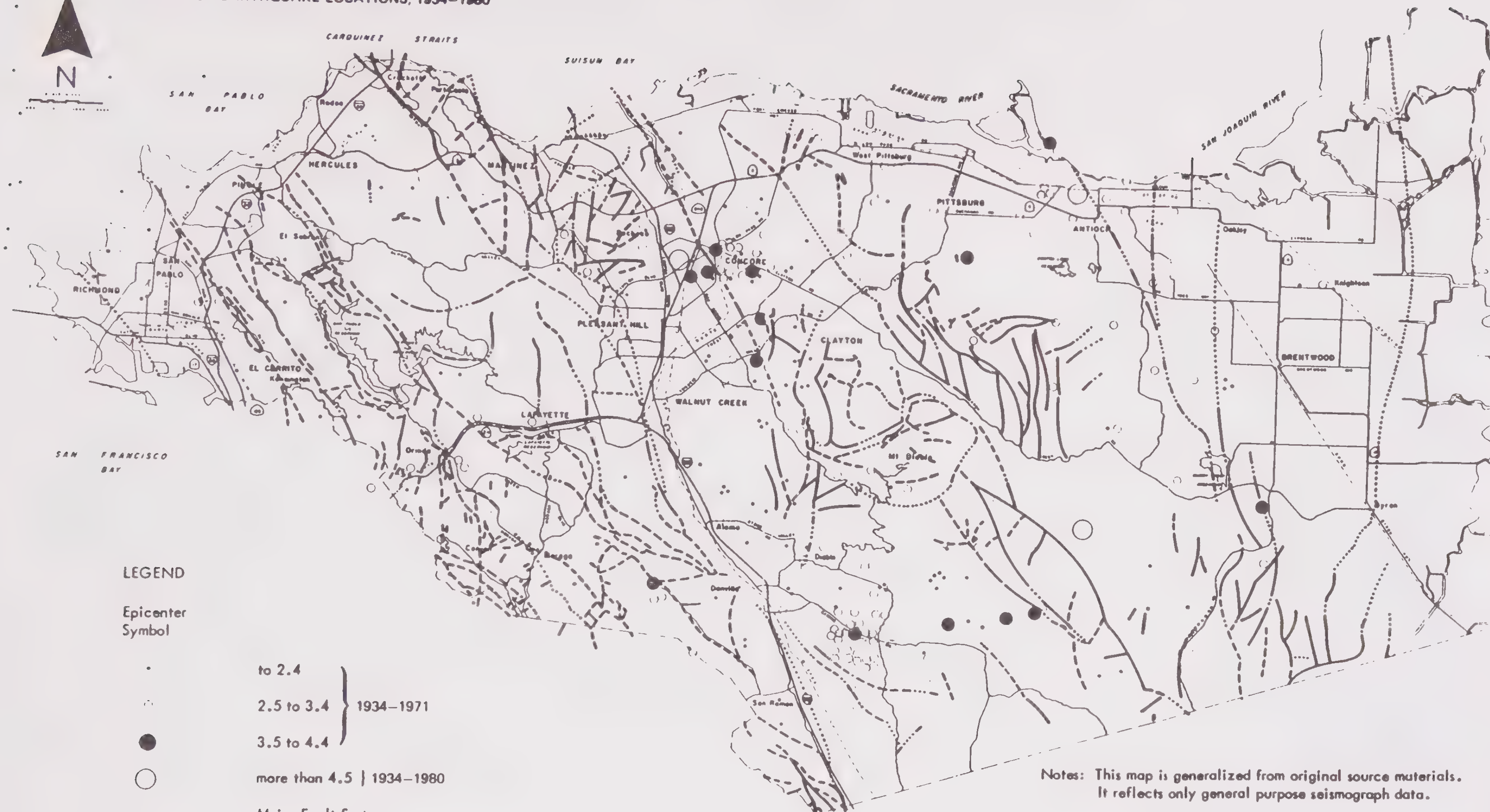
ANTIOCH

Alamo

CONTRA COSTA COUNTY
CALIFORNIA

Prepared by the Contra Costa County Community Development Department, Contra Costa County, California.

FIGURE 2 EARTHQUAKE LOCATIONS, 1934–1980



LEGEND

Epicenter Symbol

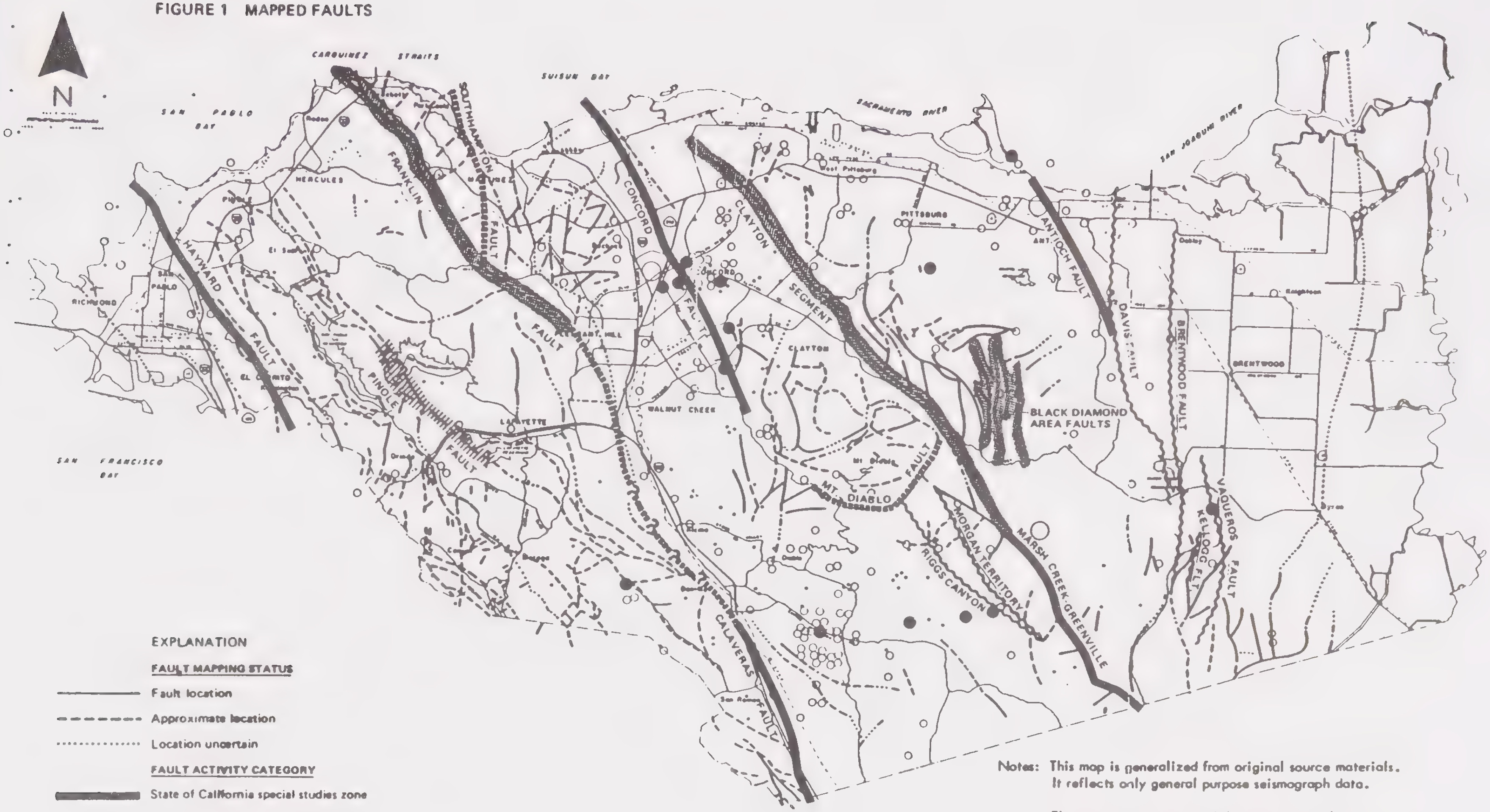
•	to 2.4	1934–1971
·	2.5 to 3.4	1934–1971
●	3.5 to 4.4	1934–1971
○	more than 4.5	1934–1980
— - —	Major Fault Systems	

Compiled by the Contra Costa County Community Development Department from the University of California (Berkeley) Seismograph Station Records.

Notes: This map is generalized from original source materials. It reflects only general purpose seismograph data.

The apparent scattering of the epicenters relative to fault locations is due to instrumentation and measurement problems as well as the dip of the faults and other factors.

FIGURE 1 MAPPED FAULTS



EXPLANATION

FAULT MAPPING STATUS

- Fault location
- Approximate location
- Location uncertain

FAULT ACTIVITY CATEGORY

- State of California special studies zone
- Faults with reported Late Pleistocene displacement but not in a state of California special studies zone

FAULTS WITHOUT EVIDENCE OF LATE PLEISTOCENE OR HOLOCENE SURFACE DISPLACEMENTS

- Faults associated with earthquake swarms
- Faults inferred active on the basis of scattered small magnitude earthquakes near the trace of the fault
- Faults inferred active on the basis of a tectonic model

Notes: This map is generalized from original source materials. It reflects only general purpose seismograph data.

The apparent scattering of the epicenters relative to fault locations is due to instrumentation and measurement problems as well as the dip of the faults and other factors.

Prepared by the Contra Costa County Community Development Department, Contra Costa County, California.

100 Pringle Avenue, Suite 300
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415-945-3000

Woodward-Clyde Consultants

January 17, 1986
16613A/2000

Contra Costa County Community Development Department
Administration Building North Wing
Pine and Escobar Streets
P.O. Box 951
Martinez, CA 94553

Attention: Mr. Todd Nelson

Subject: Revisions of Portions of
Contra Costa County Seismic Safety Element

Gentlemen:

Please find enclosed several copies of revisions of portions of the Contra Costa County Seismic Safety Element. This work included revision of portions covering liquefaction, and active faults and seismicity, in accordance with our contract 31853-00-16236. We have previously submitted copies of the revised 1:24,000 scale liquefaction potential Administration Maps, and the originals for the enclosed Figures 1, 2 and 3 (Mapped Faults, Earthquake Locations, and Estimated Liquefaction Potential).

Enclosed are the text describing the results of our evaluation of active faulting and seismicity, and liquefaction potential in the County. Also enclosed are Table I summarizing data on active faults affecting the county, and Table II estimating maximum earthquake parameters for known faults affecting the county. Also enclosed is a print of Contra Costa County at a scale of 1:24,000 on which we have located significant faults.

The liquefaction evaluation was performed by Lelio Mejia, Senior Project Engineer, and the active faulting and seismicity evaluation was performed by Ross Wagner, Senior Staff Geologist. We have enjoyed working with you on this interesting project. Please contact us if you need additional consultation, or if you have any questions.

Sincerely,

WOODWARD-CLYDE CONSULTANTS

Albert P. Ridley
Senior Project Geologist

APR/ggw
2258r

REVISION OF PORTIONS OF
CONTRA COSTA COUNTY SEISMIC SAFETY ELEMENT

INTRODUCTION

A considerable amount of new information has become available regarding the seismic hazards in Contra Costa County since the Seismic Safety Element of the Contra Costa County General Plan was adopted in 1975. Therefore, the Contra Costa County Community Development Department has directed the revision of portions of the Seismic Safety Element to include much of this new information. The revision effort was directed towards two portions of the Seismic Safety Element: Active Faulting and Seismicity, and Liquefaction Potential. The scope of work and the results of these efforts are described below.

ACTIVE FAULTING AND SEISMICITY

SCOPE OF WORK

This effort consisted of a review of existing literature to identify faults which have been inferred to be active and an attempt to describe some of the characteristics of these faults. Fault characteristics include geomorphic indicators, historic seismicity, the presence of surface rupture or creep, and maximum credible and maximum probable earthquake. The results of this work include: a revised fault map (figure 1), a revised seismicity map (Figure 2), a revised administrative map of faults at a scale of 1:24,000, and a summary of fault activity criteria and estimated earthquake magnitudes (Table I).

A variety of criteria are used in the literature to establish whether a fault is active. These criteria range from those which are definitive, such as active creep or major earthquakes with surface rupture, to those which are more speculative, such as proposed tectonic models which would require that a given fault be active. In the following discussion, faults are grouped according to the criteria which have been used to infer activity. Those with the most definitive criteria are discussed first. The first two categories consist of faults which are known, or inferred from field studies to have experienced surface displacements during the late Pleistocene or Holocene (approximately the last 10,000 years). Faults in the remaining categories have no reported evidence for geologically recent surface displacements and hence less confidence can be placed in the assessment that they are active.

Maximum credible and maximum probable earthquakes are defined by the California Division of Mines and Geology (CDMG Note 43, 1975) as follows:

Maximum Credible Earthquake

"The maximum credible earthquake is the maximum earthquake that appears capable of occurring under the presently known tectonic framework. It is a rational and believable event that is in accord with all known geologic and seismologic facts. In determining the maximum credible earthquake, little regard is given to its probability of occurrence, except that its likelihood of occurring is great enough to be of concern. It is conceivable that the maximum credible earthquake might be approached more frequently in one geologic environment than in another."

Maximum Probable Earthquake

"The maximum probable earthquake is the maximum earthquake that is likely to occur during a 100-year interval. It is to be regarded as a probable occurrence, not as an assured event that will occur at a specific time."

Procedures for estimating maximum earthquake magnitudes generally relate some measurable characteristic of a fault to the maximum earthquake which could occur on the fault. Rupture length and rupture area, for example, are commonly used to evaluate the maximum magnitude on a given fault. Unless otherwise stated, earthquake magnitudes presented in this report are expressed in the M_s magnitude scale. All earthquake magnitudes presented in the literature have been recalculated using equations presented by Schwartz & others (1984) and the same fault parameters as used in the cited literature. As a result, some of the magnitudes shown in Table I, in some cases, differ slightly from those shown in the cited literature.

<u>Faults Which Have Produced Historic Earthquakes, Exhibit Creep, And Are Included In State California Special Studies Zone</u>

<u>Hayward Fault</u>. A part of the Hayward fault (Figure 1) lies at the western edge of Contra Costa County in the cities of Richmond and San Pablo. Major earthquakes, one with surface rupture, occurred on the Hayward fault in 1836 and 1868 (Toppazada and Park 1982). Creep has been identified at a number of locations along the fault (Hirschfield, 1982; Radbruch 1968), and the fault is well defined by a zone of microseismicity (Ellsworth and others 1982). Geodetic measurements show a slip rate of 7 $\pm$1 mm/year on the Hayward fault (Prescott and others 1981). Most of the surface trace of the fault is sufficiently well defined that it has been placed in a special studies zone by the State of California (1982). It should be noted that in the reach of the Hayward fault in the Berkeley Hills in Contra Costa County the surface expression is disrupted in many places by massive landslides, and that fault traces may not be reliable indicators, everywhere, of future locations for surface rupture.

The maximum credible earthquake for the Hayward fault has been estimated by several authors and their results are shown in Table I. Two of these estimates (Slemmons & Chung 1982, Shedlock & others 1980) give

maximum values in excess of 7.5. The estimates of Shedlock and others (1980) are based on the relation between rupture length and magnitude and the assumption of a 100% rupture on a 190 km long fault that includes the Hayward fault and the most active, southern part of the Calaveras Fault. This rupture would extend from the southern end of the Calaveras fault near Hollister, northward to Calaveras Reservoir, where it would break across the East Bay Hills, join the southern end of the Hayward fault, and extend northwesterly to San Pablo Bay. The connection between the Calaveras and Hayward faults is probably made because: 1) near Calaveras Reservoir, the two are linked by a thin linear belt of microseismicity (Ellsworth and others 1982) and, 2) geodetic studies show that part of the slip on the southern part of the Calaveras fault is transferred to the Hayward fault in the same area (Prescott and others 1981).

The geodetic and seismic data make it impossible to disprove that a rupture could connect the two faults, however the absence of evidence for surface faulting in the area (Hart and others 1981) suggests that it is unlikely that the two faults would rupture as a unit. The estimates of maximum earthquake magnitudes based on this interpretation are, therefore, probably too high.

Slemmons & Chung (1982) defined the Hayward fault zone as including the southern end of the Calaveras fault to the vicinity of Calaveras Reservoir, the Hayward fault along the east side of San Francisco Bay and the Rodgers Creek and Maacama faults to the north of San Francisco Bay. They then consider this entire 280 kilometer long feature as a single throughgoing structure for purposes of earthquake magnitude estimates. For the reasons discussed above these fault length estimates are probably too long. However, since Slemmons & Chung (1982) estimate a rupture length of only 19% of this total length, their magnitude estimate (using the length to magnitude relationship) is actually lower than that of Shedlock and others (1980). Slemmons and Chung (1982) also estimate the maximum credible earthquake on the Hayward fault using a variety of other methods, some of which are independent of the total length of the fault.

Applying these different approaches to the Hayward fault they conclude that the range of maximum earthquake magnitudes is 6 to 8 with most data suggesting magnitudes of 7 ± ¼.

Those magnitudes reported by Slemmons & Chung (1982) which relate maximum magnitude to fault length are probably too high due to an excessive estimate of fault length, however none of these methods give earthquake magnitudes which exceed 7.1. This, when taken in conjunction with the other approaches used by Slemmons & Chung (1982), suggests that 7¼ is a conservative value for the maximum credible earthquake for the Hayward fault. A value of 6 1/2 has been selected for the maximum probable earthquake.

<u>Calaveras Fault</u>. The Calaveras fault lies in the south central part of the county along the western side of the San Ramon Valley (Figure 1). The northward extention of the fault and its relationship to other faults are both unclear because the literature contains a variety of structural interpretations and contradictory fault names.

With respect to fault names, Lawson (1914) and Ham (1952) used the name Franklin fault for the northern projection of the Calaveras fault in the vicinity of Tice Valley and Alamo. Saul (1973) and Dibblee (1980e), on the other hand, referred to the fault in this area as the Calaveras fault. Because Lawson (1914) originally used the name Franklin fault to a point south of Tice Valley we will also use that name in that area.

The boundary between the two faults is chosen here as the north end of the special studies zone defined on the Calaveras fault in the San Ramon Valley. This boundary is in the southern most part of the town of Danville, approximately 2 miles north of the town of San Ramon.

The Calaveras fault experienced an earthquake with surface rupture in the southern part of Contra Costa County in 1861. The magnitude of that earthquake has been variously estimated at 5.6 (Toppozada & others, 1981)

to 6 (Wesson & others 1975). The 1861 surface rupture may have extended into the southern end of what is here called the Franklin fault. Moderate-sized earthquakes with surface rupture have occurred on the fault to the south of the county. No creep is currently known to be occurring on the Calaveras fault within Contra Costa County, although creep does occur on the southern reach of the fault.

South of Calaveras Reservoir the fault is well defined by a thin linear belt of microseismicity, however, north of the reservoir, in Alameda and Contra Costa Counties, there is no direct association between the fault and microseismicity (Ellsworth and others, 1982)

In southern Contra Costa County the geomorphic expression is sufficiently well developed that it has been placed within a Special Studies Zone by the State of California. The Special Studies Zone is terminated at a point approximately 2 miles north of San Ramon on the east flank of Las Trampas Ridge (Earl Hart, 1981).

Most estimates of the maximum credible earthquake magnitude for the Calaveras fault cluster around 7.0 (Table I). Shedlock and others (1980), however, estimate a maximum magnitude of 7.5. This interpretation is based on the assumption of a rupture length equal to 100% of the total length of the Calaveras fault between its southern end near Hollister and its northern end near San Ramon. Because most earthquakes rupture less than 100% of the total fault length (North American examples range from 2 to 75 percent of total fault length, (Wentworth and others, 1969)) this estimate is probably too high.

Slemmons & Chung (1982) define the Calaveras Fault zone as consisting of the Calaveras fault from a point near Hollister northward to the vicinity of Danville, the Concord fault from Danville to Suisun Bay and the Green Valley fault north of Suisun Bay. For purposes of seismic assessment they assume these three structures function as a single 280 kilometer long fault. The precise connection between the Calaveras

and Concord faults is not clear, however, both Weaver & Hill (1979) and LaViolette & Wigginton (1983) have suggested that at least some of the right lateral displacement on the Calaveras fault is being transferred to the Concord fault in the vicinity of Danville and that the Danville earthquake swarms of 1970 and 1976 are a manifestation of this transfer of displacement. Well-documented stepover distances on strike-slip faults have reached a maximum of 3 kilometers (Bonilla, 1979). Because the proposed stepover from the Concord to the Calaveras faults takes place across a distance of approximately 7 kilometers, it seems unlikely that a single rupture would join these faults. As a result, those estimates of Slemmons & Chung (1982) which relate maximum credible earthquake to fault length are probably too high. Slemmons & Chung (1982) also used methods which are independent of fault length. When all of the data was considered, they concluded that the maximum credible earthquake for the Calaveras fault could range from 6-8, but that most of the data suggest a value of 7 $\pm$ 1/4.

Because some of the estimates of Slemmons & Chung (1982) are probably too high, a value of 7-1/4 is considered a conservative value for the maximum credible earthquake for the Calaveras fault. A value of 6-1/2 has been selected for the maximum probable earthquake.

Greenville Fault--Marsh Creek-Greenville Segment. The Greenville fault (Figure 1) is a major tectonic element in Central Contra Costa County which extends from Livermore Valley northwesterly to Suisun Bay. Because of earlier uncertainties concerning the continuity of faulting, parts of the Greenville fault have, in older literature, been given different names. In particular, the part of the Greenville fault to the north of Mt. Diablo has been called the Clayton fault, however more recent work (see for example Earth Science Associates, 1982) has shown the fault to be a continuous feature. Earth Science associates (1982) divided the Greenville fault into three segments based on geomorphic expression and stepovers along the strike of the fault. The Arroyo Mocho Segment extends from the southeast corner of Livermore Valley southeasterly for

at least 28 kilometers. The Marsh Creek-Greenville Segment extends from the southeast corner of Livermore Valley northwesterly to a point southeast of the summit of Mt. Diablo, while the Clayton segment extends along the east side of Clayton Valley northward from the north end of the Marsh Creek-Greenville segment. The Clayton segment is discussed on Page 16.

Two moderate earthquakes (magnitudes reported were 5.4 to 5.8 and 5.2 to 5.8) occurred on the Marsh Creek-Greenville segment in January of 1980 (Bolt and others, 1981, and Bonilla and others 1980) (Figure 2). These earthquakes were associated with surface rupture (Bonilla and others, 1980).

Abundant microseismicity occurred along the fault trace after the earthquakes of 1980 (see for example Ellsworth and others, 1982). The State of California has zoned this segment of the Greenville fault as a Special Studies Zone (1982).

Two somewhat different estimates have been made for the maximum credible earthquake on the Marsh Creek-Greenville Segment. Earth Science Associates (1982) believes the Marsh Creek Segment will rupture independently from the rest of the Greenville fault and estimates a maximum credible earthquake of 6.5. This is based on a rupture of approximately 2/3 of the total segment length.

Shedlock and others (1980) suggest a maximum credible earthquake of 6.9. Their interpretation is based on a 100% rupture of a 50 km long fault. It is difficult to evaluate Shedlock and others (1980) because of inconsistencies between fault lengths shown on figures and those discussed in the text. The Greenville fault as shown in Figure 1 and 2 of Shedlock and others (1980) extends from the central part of the Marsh Creek-Greenville Segment of Earth Science Associates (1982) southward into the Arroyo Mocho Segment. Figure 1 (Shedlock and others, 1980) shows the fault to be approximately 40 km long and Figure 2 shows it to

be approximately 30 km long. There is no discussion in the text of Shedlock and others (1980) of how the 50 km length was obtained.

Because Earth Science Associates (1982) reports differing geomorphic expression between the Arroyo Mocho and the south end of the Marsh Creek-Greenville Segments, and because Hart (1981a) does not recognize evidence for recent faulting to the north of the north end of the Marsh Creek-Greenville Segment of Earth Science Associates (1982), the suggestion that this is a rupture segment is accepted and a maximum credible earthquake of 6-1/2 is assigned to the Marsh Creek-Greenville Segment. A maximum probable earthquake of 5-3/4 has been selected for the Marsh Creek-Greenville Segment.

The Concord Fault. The Concord fault (Figure 1) is a northwest striking feature which lies along the east side of Ygnacio Valley extending from south of Ygnacio Valley Road through downtown Concord and into Suisun Bay (Sharp, 1973; State of California 1974a, 1974b, 1974c). The southern end of the fault is located in the hills to the west and southwest of Mt. Diablo near the southeastern part of the town of Walnut Creek. The fault can be traced northward into Suisun Bay where it lies approximately along strike of the Green Valley fault - a fault located outside of Contra Costa County, but one which is identified as being active (Frizzell and Brown, 1976). The fault was probably the source of the magnitude 5.4 earthquake of October 1955 (Sharp, 1973). Creep has been reported along the Concord fault by both Sharp (1973) and Galehouse and others (1982), and the central part of the fault is well defined by a belt of microseismicity (Ellsworth and others 1982).

The surface expression of the fault is sufficiently well developed that it has been placed in a Special Studies Zone by the State of California (1974a, 1974b, 1974c).

Estimates of the maximum credible earthquake magnitude for the Concord fault range from 6 to 8, however, except for the analysis of

Slemmons & Chung (1982, see Table 1), they cluster in the 6.0 to 6.5 range. The results of Slemmons & Chung (1982) differ from the other analyses for a number of reasons. First, because they have treated the Calaveras, Concord, and Green Valley faults as a single through going feature, and hence, their calculations are based on a greater total length than if these faults are analyzed separately. As has been discussed in the assessment of the Calaveras fault, it seems very unlikely that the Calaveras and Concord faults would be joined by a single rupture because of the large lateral step between the two faults. In addition, the proposal that the Green Valley and Concord faults could be connected by a throughgoing rupture is one which other studies have disagreed with. Earth Science Associates (1982) suggested that the Green Valley and Concord faults would rupture independently of one another because of an 11 degree difference in the strike of the faults, an approximate 1 mile wide right step between the north end of the Concord fault and the south end of the Green Valley fault, and a change in the sense of vertical displacement.

Secondly, Slemmons & Chung (1982) used parameters which change along the strike of the structures. For example, relationships have been developed between slip rate and magnitude, and these data suggest that the Calaveras fault zone would produce maximum credible earthquake magnitude of from 6.7 to 7.8. However, the slip rate is higher on the Calaveras fault than on the Concord fault, and hence the maximum credible earthquake inferred on the Concord fault would be lower than that inferred for the Calaveras fault zone as a whole.

Excluding the values of Slemmons & Chung (1982), estimates of maximum credible earthquake range from 6.0 to 6.5, and based on these interpretations a magnitude of 6 1/2 has been selected as the preferred value for the maximum credible earthquake on the Concord fault (Table I). A maximum probable earthquake of 5-3/4 has been selected for the Concord fault.

Antioch Fault. The Antioch fault is a northwest striking structure which runs through the city of Antioch in the eastern part of Contra Costa County (Figure 1). The fault extends approximately 3 miles south of Antioch where it joins the Davis Fault (Burke and Helley, 1973). No major earthquakes have been unequivocally associated with the Antioch fault, although it may have been the source of the 1889 Collinsville earthquake which reached a Modified Mercalli Intensity of VII at Antioch and Collinsville in Solano County (Coffman and others, 1981). This earthquake had an estimated magnitude of 6.0 and surface rupture may have occurred in Antioch (Toppozada & others 1981).

In September of 1965 an earthquake swarm occurred just southwest of Antioch. The epicenters of these earthquakes occupied a north-northwest trending zone which lies slightly more than 2 kilometers west of the mapped trace of the Antioch fault.

There is uncertainty as to whether the Antioch fault is currently experiencing creep, but the majority of data currently available suggest that creep is occurring. Burke and Helley (1973) interpreted damage to cultural features in the Antioch region as resulting from creep on the fault. Galehouse (1982) performed geodetic surveys across the Antioch fault, and concluded that episodic creep might be occurring, but that it is probable that nontectonic movements influenced the results of the geodetic survey. Knuepfer (1977) stated that the magnitude of offsets observed on curbs and streets was generally within the realm of concrete expansion and contraction cracks. However, he identified 5 locations where this explanation did not appear to be sufficient (Knuepfer, 1977 p. 29).

On the basis of relationships exposed in a cut bank, Earth Science Associates (1982) concluded that "the age of the last offset (on the Antioch Fault) must be Post-Pliocene, and is most likely Holocene." Similar relationships also occur outside the state's special studies zone near the intersection of Lone Tree Way and East Tregallis Road (Todd

Nelson, Personal Communication, 1985). The surface expression of the fault was interpreted to be sufficiently well developed that the State of California (1976a, 1976b) has placed it in a special studies zone.

Three estimates of maximum credible earthquake magnitude have been made for the Antioch fault (Table I). Two of these, 6.6 by Wesson & others (1975) and 6.5 by Woodward-Clyde Consultants (1984), are consistent with one another, but the third, 5 3/4 by Earth Science Associates, (1983), differs substantially. According to Earth Science Associates (1983, p 66) the magnitude value of 5 3/4 was obtained by applying the curves of Slemmons (1977) to a 12 km long rupture length. A review of Slemmons curves (1977, p 91) shows that a 12 km long rupture length on a strike-slip fault (curve E on Slemmons, 1977, Figure 27) would produce an earthquake with a magnitude of approximately 6.1. If the regression equations of Schwartz & others (1984) are applied to a 12-km-long rupture the magnitude is approximately 6.2. A conservative value of 6 1/2 has been selected as the preferred value for the maximum credible earthquake on the Antioch fault (Table I). The preferred value for the maximum probable earthquake has been chosen as 5-3/4.

<u>Faults Located Outside Of Contra Costa County Which Have Produced Major Historic Earthquakes, Exhibit Creep, and Are Included In A State of California Special Studies Zone</u>

<u>San Andreas Fault</u>. The San Andreas fault is located outside of Contra Costs County, however, because it is capable of producing a very large earthquake and strong ground motions within the County, it will be considered briefly here.

The fault is a northwest striking feature which extends from Mexico to northern California. In the Bay Area it is located on the San Francisco Peninsula, offshore of the Golden Gate Bridge and in Marin County between Bolinas Lagoon and Tomales Bay. At its closest approach, it lies 15-16 miles southwest of the City of Richmond.

The San Andreas was the source of the Richter magnitude 8-1/4 earthquake of 1906, and it displays creep and microseismicity in areas south of the San Francisco Bay area. During the 1906 earthquake, approximately 20 feet (6 meters) of right lateral strike slip displacement was observed in Marin County. Wesson & others (1975) estimate a maximum Richter magnitude of 8-1/2 for the San Andreas Fault. The preferred value for the maximum probable earthquake has been chosen as 8-1/4.

Faults With Reported Late Quaternary or Holocene Displacements But Without Sufficient Geomophic Expression To Be Included In a State Of California Special Studies Zone.

Franklin Fault. As has been previously discussed, existing maps show the Calaveras and Franklin faults to be a continuous structure which extends along the west side of the San Ramon Valley (Figure 1). In this discussion the location at which the name changes from Calaveras to Franklin Fault has been chosen to occur at the north end of the State of California special studies zone on the east flank of Las Trampas Ridge approximately two miles north of the town of San Ramon.

The location of the Franklin fault north of Alamo is uncertain. Although differing in detail, regional mapping by Lawson (1914), Ham (1952), Saul (1973), and Dibblee (1980d, 1980e) indicate that it can be traced along the east flank of Las Trampas Ridge, and the east side of Tice Valley. Ridley and others (1982), however, trenched the mapped trace of the fault just east of Tice Valley and reported that no bedrock fault with strike-slip characteristics exists at that location. Although clear evidence for strike-slip displacement is lacking, there are relatively complex relationship between the Franklin and other faults in this area and it is possible that deformation is distributed through a relatively wide zone and that some of the faults within this zone show primarily dip slip movements. Studies by Woodward-Clyde Consultants (1979a, 1979b) identified a dip slip fault along the east side of Tice Valley.

To the north of Highway 24, Lawson (1914) shows the Franklin fault to be a continuous feature from the Walnut Creek area to the Carquinez Straits. Saul (1973) shows what he called the Calaveras fault to extend as a continuous feature to the north edge of his study area in Pleasant Hill. Dibblee (1980b, 1980e), shows the Franklin fault (he calls it the Calaveras fault) joining the Southampton fault in Walnut Creek, and shows the Southampton fault extending into the Carquinez Straits near Martinez. Dibblee (1980b, 1980c, 1980e) shows the Franklin fault as extending from the Carquinez Straits near Crockett southeastward to Pleasant Hill. At this point, he ends the Franklin fault and leaves an approximately 350 meter wide (1000 foot) gap between it and the adjacent Southampton fault.

It is not possible, from information available at this time, to resolve the conflict between the various interpretations of the location of the Franklin fault. For purposes of this analysis, the conservative assumption will be made that the Franklin and Calaveras faults are a continuous bedrock feature which extends along the east flank of Las Trampas ridge through the vicinity of Tice Valley and northwesterly to the Carquinez Straits.

Quaternary surface activity on the Franklin fault has been evaluated in trenches excavated within a few feet of the main trace of the fault in the vicinity of Franklin Canyon. Exposures in the trenches show multiple displacements in the past 35,000 to 40,000 years and some recurrent offset of colluvium estimated to be on the order of from as young as 8,000 to 12,000 to as old as about 20,000 years old (Earth Science Associates, 1983).

An evaluation by the California Division of Mines and Geology showed that there was not sufficient geomorphic expression for the fault to be included in a special studies zone (State of California, 1974c).

Whether all of the Franklin fault has experienced Holocene or Late Quaternary movement is difficult to evaluate with the data currently

available. At its northern end trenches excavated by Earth Science Associates (1983) show late Pleistocene and possibly Holocene displacement. To the south, through Pleasant Hill, Walnut Creek and the San Ramon Valley, there is no clearly documented evidence for late Quarternary displacements. For example, several studies done in Tice Valley have indicated that no late Quaternary displacement has occurred on the fault at that location. (Woodward-Clyde Consultants 1978, 1979a, 1979b).

At its southern end, where it joins the special studies zone located at the north end of the Calaveras fault, it might be expected to show Holocene displacements. However, some authors (Weaver & Hill 1979, and LaViolette & Wigginton 1983) have suggested that at least some of the right lateral displacement on the Calaveras fault is being transferred eastward to the Concord fault. This would suggest that no displacement, or a reduced rate of displacement, is occurring along the Franklin fault, located to the north of this zone of transfer. Because of the uncertainties in connections between the Franklin and other faults and because of the relative lack of data on Quaternary history along much of its length, in this report the southern part of the fault has been included in the fault activity category "inferred active on the basis of a tectonic model". The southern end of the area included in this category is placed at the northern end of the Special Studies zone just north of San Ramon. The northern boundary is placed in Pleasant Hill at the point where the trace of the Franklin fault passes from alluvium (on the south) to bedrock (on the north).

No major earthquakes can be unequivocally associated with the Franklin fault, although it is possible that the 1898 Mare Island earthquake, having an estimated magnitude of 6.2 (Toppozada & others 1981), may have occurred on this fault (Table I). No historic surface faulting or creep have been reported on the fault and it is not associated with microseismicity (Ellsworth & others 1982).

Earth Science Associates (1983) estimated a maximum credible earthquake magnitude of 6-1/4 for the Franklin Fault (Table I). Considering the available data, this appears to be a reasonable estimate for the preferred magnitude of the maximum credible earthquake. Because there is insufficient data upon which to make an assessment, no maximum probable earthquake has been assigned to the Franklin fault.

Greenville Fault--Clayton Segment. The Clayton Segment is on the northern projection of the Greenville fault, a structure which produced earthquakes with surface rupture in January of 1980. As defined by Earth Science Associates (1982) the Clayton segment extends from a point southeast of the summit of Mt. Diablo northwesterly along the eastern edge of Clayton Valley to the vicinity of Port Chicago.

No major earthquakes are known to have occurred on this fault, nor does it display surface creep or a strong pattern of microseismicity, although scattered microseismicity in the area of the fault could be attributed to it (Personal Communication, Pat Gomez, Beta Associates, 1985). A number of consultant reports developed for proposed subdivisions have reported surface displacements interpreted to be Quaternary or Holocene in age near the south end of the fault (Woodward-Lundgren and Associates, 1974), however, the geomorphic expression of the Clayton segment is not sufficiently strong to include it in a Special Studies Zone (State of California 1974a, 1974b).

As shown in Table I a preferred magnitude of 6 1/4 has been selected for the maximum credible earthquake on the Clayton segment of the Greenville fault. This is primarily based upon the estimates of Earth Science Associates (1982, 1983). In addition, an estimate of 5-1/2 has been selected for the maximum probable earthquake.

Black Diamond Area Faults. The Black Diamond area faults consist of five north-south to northwest striking faults (Figure 1). These structures include the Keller Ridge, Oil Canyon, Stewartville, and Long Canyon

faults, as well as an unnamed fault which lies between the Long Canyon and Stewartville fault (see Brabb and others 1971, Dibblee 1980a, and ESA, 1982). Names and precise locations of these faults differ depending on which of the above references is used. The terminology and fault locations used by Brabb and others (1971) are used here.

No notable historic earthquakes are known to have occurred on these faults, nor are there any reports of surface rupture, and they are not included in a special studies zone (State of California 1976b). Scattered, relatively low density clusters of microseismicity occur in the area of these faults (Ellsworth & others 1982), but no clear spacial relations with the faults are evident (Figure 2). Earth Science Associates (1982) excavated trenches across the northern end of the Stewartville fault and an unnamed fault just east of it. They observed deformation of soil and colluvium in these trenches and concluded that: "there remains the possibility that the observed relationships (displacement of soils) are the result of minor folding and/or local landslidings. In general, however, the evidence indicates that the Stewartville Fault and related north-trending faults in the area are minor old tectonic features with possible minor late Quaternary movement. They are therefore, considered to be potentially seismogenic."

On this basis these faults are considered, in this study, to have experienced Quaternary movements, but the level of confidence in this interpretation is lower than for other faults having reported Quaternary displacements. Based upon work performed by Earth Science Associates (1982) it appears reasonable to estimate a maximum credible earthquake of about 5 1/2 for these faults (Table I). Because there is insufficient data, no maximum probable earthquake has been assigned to these faults.

<u>Faults Inferred To Be Possibly Active Because Of Association With Earthquake Swarms</u>

<u>Pinole Fault</u>. The Pinole fault is a northwest striking feature which extends from the City of Pinole southeastward at least as far as Orinda (Figure 1). No known significant earthquakes have occurred on this fault

nor is any creep known to be occurring. The State of California originally included the northern end of the Pinole fault in a special studies zone, but later work by geologists of the California Division of Mines and Geology resulted in its being removed from the zone (Bedrossian, 1980).

Microseismic activity may have occurred on the Pinole fault in 1977. In January of that year a small swarm of earthquakes occurred in the Briones Hills. The epicenters of these earthquakes plot as a northwest trending belt coincident with the trace of the Pinole fault (Figure 2) (Bolt and Others, 1977).

An analysis of focal mechanisms by Bolt and Others (1977) indicates a northwest striking southwest dipping right lateral strike slip fault was responsible for the 1977 Briones Hills swarm. On the basis of the southwest dip of the focal plane, Bolt suggests that the swarm may have occurred on faults located to the east of the Pinole fault. However, because of the close spacial relationship between the surface trace of the Pinole Fault and the epicenters of the 1977 swarm, the Pinole Fault is tentatively interpreted in this analysis to be the source of the swarm. No estimates of maximum earthquake magnitudes have been made for this fault.

<u>Faults Inferred To Be Active Because Of Scattered Microseismicity In The Vicinity Of The Surface Trace Of The Fault</u>

Earth Science Associates (1982) and the California Department of Water Resources (1978) have inferred several faults to be potentially seismogenic on the basis of scattered microearthquakes having occurred in the vicinity of the surface trace of those faults. Faults included in this category are the Riggs Canyon and Morgan Territory faults, located just southeast of Mt. Diablo; and the Brentwood, Vaqueros, and Kellogg faults, located in the low hills between Antioch and Byron. None of these faults are known to have experienced significant earthquakes or surface rupture, and none are known to display creep. None of these

faults are included in State of California Special Studies Zones (see Figure 1). No estimates have been made of possible maximum earthquakes on these faults.

The Davis fault (Figure 1) is also included in the category; however the data concerning this fault are complex and subject to various interpretations. The Davis Fault is a north-northwest striking structure which lies to the east of Antioch and extends southward to the vicinity of Kellogg Creek. Burke and Helley (1973) show the Antioch fault to splay northwesterly from the Davis fault in the vicinity of Antioch and they report 15-cm-high scarps in alluvium on the Davis fault south of its intersection with the Antioch fault. The State of California (1976) has included this same part of the Davis fault in a special studies zone.

The California Department of Water resources (1978) has reported on trenches excavated across the fault within the special studies zone. One of these trenches crossed the scarp reported by Burke and Helley (1973). It showed an unbroken sequence of soils estimated to the 50,000 to 100,000 years old which overlies a possibly faulted 200,000 year old soil. It was further reported that none of the trenches excavated south of this locality showed any signs of displacement in soils estimated to be 50,000 to 70,000 years old.

The Department of Water Resources (1978) also reported that microseismicity was occurring along the Davis fault and concluded "The present pattern of activity is one of small earthquakes -- apparently so small they have not broken the ground surface within the last 50,000 to 100,000 years." Earth Science Associates (1982) also concluded that the Davis fault is potentially seismogenic on the basis of scattered microseismicity occurring in the vicinity of the trace of the fault.

Contradictory interpretations by Burke and Helley (1973), the State of California (1976), and the Department of Water Resources (1978) do not unequivocally establish whether the Davis fault has experienced

Quaternary displacement. In the absence of any clearly defined Quaternary displacements in trenches excavated by the Department of Water Resources (1978) the fault is included in the Category "Active on the basis of Scattered Epicenters occurring in the vicinity of the trace of the fault." By placing the fault in this category the part of the fault just south of its intersection with the Antioch fault is not considered to show late Quaternary displacement, even though it is included within a special studies zone. Insufficient data exists to estimate possible earthquake magnitudes on these faults.

Faults Inferred To Be Active On The Basis Of Tectonic Models

Mt. Diablo Fault. The Mt. Diablo fault (Figure 1), located along the south side of Mt. Diablo, is inferred by Earth Science Associates (1982) to be at least seismogenic if not capable of fault ground rupture. This inference is based on the interpretation that the Mt. Diablo fault acts as a zone of transfer of right lateral displacement from the Greenville fault to the Concord fault.

Southampton Fault. The Southampton fault (Figure 1) is a northwest striking structure which diverges from the Franklin fault a few miles northwest of Walnut Creek. No earthquakes are known to have occurred on this fault, nor has creep surface rupture been reported, and the fault is not associated with microseismicity (Ellsworth & others 1982).

Earth Science Associates (1983) has excavated trenches across the Southampton fault just north of Highway 4. They concluded that the relationships observed in these trenches "are permissive of a bedrock fault located at depth." In addition, the trenches showed an unbroken sequence of soils and colluvium overlying the possible fault trace. ESA concluded that "although the age of these surficial materials is unknown, similar materials elsewhere in the study region are at least several thousand years old (Earth Science Associates, 1983, p 24). Dibble & Darrow (reported in Earth Science Associates, 1983) suggested that right

lateral displacement on the Southampton fault has produced the northward bend of the Sacramento River in the Carquinez Straits. Earth Sciences Associates (1983, pp 23 and 51) disagree with this interpretation because the fault has little in the way of topographic expression that is suggestive of late Quaternary displacement, and trenches revealed unbroken surficial deposits overlying the trace of the fault.

Earth Science Associates (1983) concluded that, although there was no evidence for late Quaternary movement, the fact that the Southampton fault lies between two active faults (the Concord and Franklin), and along the projected trend of the Calaveras fault, it should be considered to have some seismic potential.

In addition to the Mt. Diablo and Southhampton Faults, the southern part of the Franklin Fault (Figure 1) is considered to be potentially active on the basis of a tectonic model. This interpretation has been previously discussed in the sections on the Calaveras and Franklin Faults. Insufficient data are available to make estimates of possible maximum earthquake magnitudes on the Mt. Diablo and Southampton Faults.

LIQUEFACTION POTENTIAL

SCOPE OF WORK

This effort included revisions of the liquefaction potential map (Figure 3) and revisions of the administrative maps of liquefaction potential (scale 1:24,000) used by the County staff for planning purposes. These revisions are based on existing soil data from geotechnical reports in County and Woodward-Clyde Consultants files. In addition, new advances in the evaluation of liquefaction potential and in the understanding of liquefaction phenomena are incorporated.

Boring data were evaluated using currently accepted methods and criteria for evaluation of liquefaction potential. Based on the results of these evaluations, the administrative maps were revised as the data permitted. The administrative maps were used to revise the liquefaction potential map in the Seismic Safety Element.

LIQUEFACTION

Background

Liquefaction is a natural phenomenon during which a loose saturated granular soil undergoes a loss in strength and develops a condition similar to a viscous liquid. In this state the soil is in a "quicksand" condition and can flow under gravity as a heavy liquid. During earthquakes, liquefaction may result in ground failure with potentially severe damaging effects to natural and man-made structures.

Several phenomena are commonly observed as a result of liquefaction. These include the formation of sand boils, lateral ground spreading, and

mud flows. Additionally, as the soil settles from its liquefied state, settlements of the ground surface result. If the soil deposit is dry (and therefore cannot liquefy), vibratory shaking from earthquakes may still produce compaction and accompanying settlement.

For liquefaction to occur, a vibrational disturbance of the soil, such as that produced by earthquake shaking, is usually required. If this disturbance results in a tendency for densification, and the soil is saturated and the pore water is unable to drain, excess pore water pressures will develop. This increase in pore water pressures will result in a decrease in effective stresses (intergranular friction) within the soil and a corresponding loss of strength. Depending on the duration and intensity of the disturbance, the effective stresses may be reduced to very small values resulting in a total strength loss and a liquefied state.

Liquefaction cannot occur in deposits of dense sands or clays of low sensitivity. Soils prone to liquefaction include loose to medium dense sands and silts occurring below the water table. Liquefaction of coarse gravels is rare because they are highly permeable and they dissipate excess pore water pressures rapidly.

The disturbance causing soil liquefaction can be static or dynamic. An example of a static disturbance would be an increase in external loading of a soil deposit by a structure or slope. Earthquake shaking is typical of a dynamic disturbance. In this case, the tendency for densification of certain soils results from soil strains caused by the earthquake stresses. These stresses are produced by the propagation of seismic waves through the soil deposit.

The loss of strength of liquefied soil results in a decrease of its bearing capacity and accompanying foundation failure of structures, instability of slopes, and lateral spreading of level ground. The increase in pore water pressures within the soil results in upward flow

of water, which causes the formation of sand boils and perhaps a rise in the water table. Evidence of this phenomenon is the floating of embedded structures, such as tanks and basements, which has been observed during past earthquakes. As the pore water pressures dissipate, the sand densifies. This densification causes ground surface and structural settlements.

Evaluation Of Liquefaction Potential During Earthquakes

General Approach. As previously discussed, the tendency for densification of a soil deposit during earthquake shaking results from the soil strains induced by shear stresses produced by the propagation of seismic waves. If the magnitude of the shear stresses is insufficient to produce significant strains within the soil, or the duration of strong shaking is relatively short, the seismic disturbance may not produce liquefaction. However, some increase in pore pressures and corresponding settlement may result.

The general approach for evaluation of liquefaction potential is to compare the cyclic shear stresses produced by the design earthquake with the resistance to liquefaction of a soil deposit. Because earthquakes produce irregular cyclic shear stresses during the period of shaking, the effects of an earthquake are typically represented by an equivalent number of uniform cycles of an average stress. Similarly, the resistance to liquefaction of a soil specimen is typically measured in the laboratory by repeatedly applying uniform cycles of shear stress. The liquefaction potential is evaluated by comparing the magnitude of the earthquake shear stresses with the magnitude of the stresses required to produce liquefaction of the soil in the laboratory in the same number of cycles.

Methods For Estimating Earthquake Stresses And Liquefaction Resistance. The methods used to estimate the shear stresses induced by an earthquake involve an evaluation of the dynamic response of the soil deposit during the earthquake. The dynamic response can be estimated using sophisticated numerical techniques for the analysis of seismic wave

propagation or simple methods based on estimates of peak ground surface acceleration.

Methods for evaluating the liquefaction resistance of soils range from complex laboratory testing programs to simplified comparisons with the performance of soil deposits during past earthquakes. These comparisons are typically based on some in-situ measure of the engineering characteristics of the soil deposit such as the standard penetration test blow count or the shear wave velocity.

Design Earthquake Criteria. To evaluate the liquefaction potential of a soil deposit it is necessary to determine the shear stresses produced by the design earthquake at depth. The criteria for selection of the design earthquake is typically to minimize the risk to structures and human life. This study is based on the same criteria adopted by Contra Costa County in the existing Seismic Safety Element. To take into account the varying degree of seismic risk posed by earthquakes of different magnitude, the County has adopted two design earthquakes as follows:

(1) A great earthquake on the Bay Area segment of the San Andreas fault which would have a surface wave magnitude of approximately 8.0 and would be comparable to the 1906 San Francisco earthquake.

(2) A moderate earthquake on an active fault in Contra Costa County. This event would have a Richter magnitude of approximately 6.5 and would be comparable to the 1971 San Fernando earthquake.

The great earthquake on the San Andreas fault is expected to produce peak accelerations on rock in Contra Costa County ranging between 0.15g and 0.4g. The moderate earthquake on a nearby fault is expected to produce maximum peak acceleration on rock of about .35g. These levels of peak ground acceleration on rock were used in the assessment of liquefaction potential.

The peak acceleration at the surface of a soil deposit usually differs from that expected on a rock outcrop. This difference is due to amplification or reduction of the intensity of earthquake shaking caused by the propagation of seismic waves through the soil deposits. The amplification or reduction of ground motion depends on several factors including the intensity of earthquake shaking, the engineering characteristics of the materials involved, and the depth of the soil deposit.

The effects of local soil conditions on peak ground surface acceleration can be estimated using the results of studies by Seed and Idriss, (1982). These studies indicate that at the intensity of shaking corresponding to a peak acceleration on rock of 0.35g, deep soil deposits and soil deposits containing soft to medium stiff clay and sand are expected to experience lower peak ground surface accelerations. The reduction is such that the expected ground surface acceleration is 0.3g for deep soil deposits and 0.25g for soil deposits containing soft to medium stiff clay and sand.

General Seed-Idriss Procedure. The liquefaction potential for the Contra Costa Seismic Safety Element was assessed using the simplified procedure proposed by Seed and Idriss, (1982). This procedure is based on an evaluation of the cyclic shear stresses produced by the design earthquake in terms of: 1) the peak acceleration at the ground surface, 2) the total soil stress at the particular depth of interest, and 3) a reduction factor with depth. This reduction factor accounts for the variation of ground acceleration with depth.

Using this procedure, the ratio between earthquake shear stresses and effective vertical stress at a particular depth is given by:

$$T/S' = 0.65\ (A/g)\ (S/S')\ R_d$$

where T = the average induced earthquake shear stress; S' = effective vertical stress at depth; S = total vertical stress at depth; A = peak ground surface acceleration; g = acceleration of gravity; and R_d = depth reduction factor.

The cyclic resistance of the soil is a function of the soil type, the corrected standard penetration test blow count, and the earthquake magnitude. The earthquake magnitude defines the number of stress cycles applied to the soil. The corrected standard penetration test blow count can be computed as

$$N1 = (C)(N)$$

where N1 = corrected standard penetration resistance, C = correction factor which depends on the effective stress prior to earthquake shaking and N = standard penetration test blow count. The cyclic resistance to liquefaction depends on the soil type and increases with increasing fines content and plasticity of the soil. Highly plastic clay soils are not susceptible to liquefaction.

Based on the soil type and its corrected penetration resistance the cyclic resistance to liquefaction can be obtained from the relationships published by Seed and Idriss, (1982) for different soil types and earthquake magnitudes. The factor of safety against liquefaction at any particular depth within a soil deposit can be computed by dividing the cyclic resistance by the stress ratio induced by the earthquake.

<u>Liquefaction Criteria</u>. In the evaluation of liquefaction potential for this study the same criteria previously used by the County for the existing Seismic Safety Element was adopted. Thus, sites where liquefaction potential was evaluated were classified into three categories as follows:

(1) Sites with a high potential for liquefaction. These sites contain extensive deposits of soils likely to liquefy during a moderate magnitude earthquake on a nearby fault and during a great earthquake on the San Andreas fault.

(2) Sites with a moderate liquefaction potential. These are sites with occasional lenses of sediment having a marginal liquefaction potential depending on earthquake size, duration, and sediment properties such as grain size and degree of sorting.

(3) Sites with a low potential for liquefaction. These are sites with soils unlikely to liquefy in the event of a moderate magnitude earthquake on a nearby fault or during a great earthquake on the San Andreas fault.

Soils with a high potential for liquefaction during an earthquake were defined as those having a factor of safety less than 0.9 against liquefaction. Soils unlikely to liquefy were required to have a factor of safety greater than 1.4. The liquefaction potential was judged marginal for soils having a factor of safety been. 0.9 and 1.4.

These factors of safety were selected after studying the data used in establishing the conditions presented by Seed and Idries (1982). The selected factors of safety account for scatter in the data. The data shows that in some cases liquefaction did not occur even though the factor of safety was below 1.0 and as low as 0.9. The data also incorporates cases when liquefaction occurred even though the factor of safety was higher than 1.0 and as high as 1.4.

Data Analysis. For the assessment of liquefaction potential throughout the County the sites for which geotechnical reports were available were located on copies of the administrative maps. Information regarding: 1) the soil conditions 2) the depth to groundwater at the site, 3) average blow counts for potentially liquefiable soil units, and 4) the

average depth below the ground surface to these soil units, was obtained from the geotechnical reports. Judgement was used to correct the data where it was obtained using procedures different than the standard. Based on the data, a factor of safety against liquefaction during the design earthquakes was computed for each soil unit and the site was classified with respect to liquefaction potential depending on the extent of the liquefiable materials.

Using engineering judgment, an allowance was made for seasonal variations in the water table and the quality of the data in the geotechnical reports. The results of the analyses were incorporated into the administrative maps. Where sufficient data were available, the existing contours on the administrative maps were revised. During this revision, available geological data regarding the distribution of potentially liquefiable soil units throughout the County were used.

Discussion

The results of this study are intended to be used for planning purposes only. When using the results of this study, some of its limitations should be kept in mind.

(1) The study is based on limited data. The data consisted of about 600 geotechnical reports throughout the county. A significant number of these reports were investigations with insufficient data to permit an assessment of liquefaction potential. Although liquefaction can occur at depths approaching 50 feet, a significant number of the geotechnical reports contain data to a depth of only 20 feet.

(2) Soils are known to vary markedly within short distances. The evaluation of liquefaction potential for this study is accurate at the specific location of the available borings. Extrapolation was required to draw contours of liquefaction potential based on geological information regarding stratigraphy of soil units.

(3) The present evaluation of liquefaction potential was made for specific design earthquakes. Variations in earthquake magnitude and distance may result in different outcomes than those predicted. Similarly, variations in the water table and soil conditions from those conditions that existed at the time of exploration may result in markedly different behavior.

In spite of these limitations, it is believed that the results of this study are valuable for County planning. The revised administrative maps can be used to locate areas of high risk due to liquefaction potential. Where areas of moderate to high liquefaction potential are encountered, additional investigation regarding site specific liquefaction potential may be required. Depending on these specific evaluations the need for mitigating measures can be assessed.

Ground Motion Parameters

For engineering applications, earthquake ground motions are typically characterized by parameters such as peak acceleration, peak velocity, peak displacement, duration of strong motion and response spectra for structural design. In this study the same parameters previously adopted by the County have been used. These parameters are: 1) duration of strong motion, 2) maximum or epicentral intensity, and 3) peak ground acceleration. They are summarized in Table II.

The duration of strong shaking corresponds to duration of ground motions above an acceleration level of 0.05 g. These durations were obtained using the correlations by Bolt, (1974) between earthquake magnitude and duration of strong motion. The maximum or epicentral intensity was obtained using the correlation with earthquake magnitude published by Richter, (1958).

The peak ground surface accelerations on rock shown on Table II are mean expected values. That is, values which are expected to be exceeded on 50 out of every 100 occurrences. They were obtained using

relationships between mean peak acceleration and distance from the fault for different earthquake magnitudes as published by Seed and Idriss (1982), Joyner and Boore (1981), Campbell (1981), and Sadigh (1983).

The above ground motion parameters are intended only as a guide to estimate expected or likely values of maximum ground motions.

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TABLE I SUMMARY OF AVAILABLE DATA ON INFERRED ACTIVE FAULTS AFFECTING CONTRA COSTA COUNTY

Fault Name	Historic Damaging Earthquakes	Historic Surface Faulting	Known Microseismic Activity	Estimated Maximum Credible Earthquake		Maximum Probable Earthquake	
				Preferred Magnitude	From Literature	Preferred Magnitude	From Literature
San Andreas	1838, 1906	Creep and Surface Rupture	Yes	8 1/2	8.5[1]	8 1/4	8 1/4[6]
Hayward	1836, 1868	Creep and Surface Rupture	Yes	7 1/4	7.0[1] 6.9[2] "Range 6 8, Most data suggest 7 ± 1/4"[3] 7.0[5] 6.8 - 7.0[6] 7.6[7]	6 1/2	6 3/4[6]
Calaveras	1861	Surface Rupture	None in Contra Costa County	7 1/4	7.3[1] 6.7[2] "Range 6 8, Most data suggest 7 ± 1/4"[3] 7 1/4[4][5] 6.5 - 7.2[6] 7.5[7]	6 1/2	6 1/2[6]
Franklin	1898?	None Known	No	6 1/4	6 1/4[5]	Insufficient Data	
Concord	1955	Creep	Yes	6 1/2	6.3[1] 6.0 "Range 6 8, Most data suggest 7 ± 1/4"[3] 6.5[4][5] 6.5 [illegible][7]	5 3/4	5 1/2[6]

TABLE 1 SUMMARY OF AVAILABLE DATA ON INFERRED ACTIVE FAULTS AFFECTING CONTRA COSTA COUNTY (concluded)

Fault Name	Historic Damaging Earthquakes	Historic Surface Faulting	Known Microseismic Activity	Estimated Maximum Credible Earthquake		Maximum Probable Earthquake	
				Preferred Magnitude	From Literature	Preferred Magnitude	From Literature
Greenville Clayton Segment	None Known	None Known	No	6 1/4	6.25(4)(5)	5 1/2	None
Greenville Marsh Creek Segment	1980	Surface Rupture	Yes	6 1/2	6.5(4)(5)	5 3/4	None
Greenville Segment		unknown			6.9(7)		
Black Diamond Area	None Known	None Known	Scattered clusters in areas near these faults	5 1/2	5 1/2(4)	Insufficient Data	
Antioch	1889?, 1965	Reported Creep	Yes	6 1/2	6.6(1) 5 3/4(4) 6.5(6)	5 3/4	5 1/2(6)

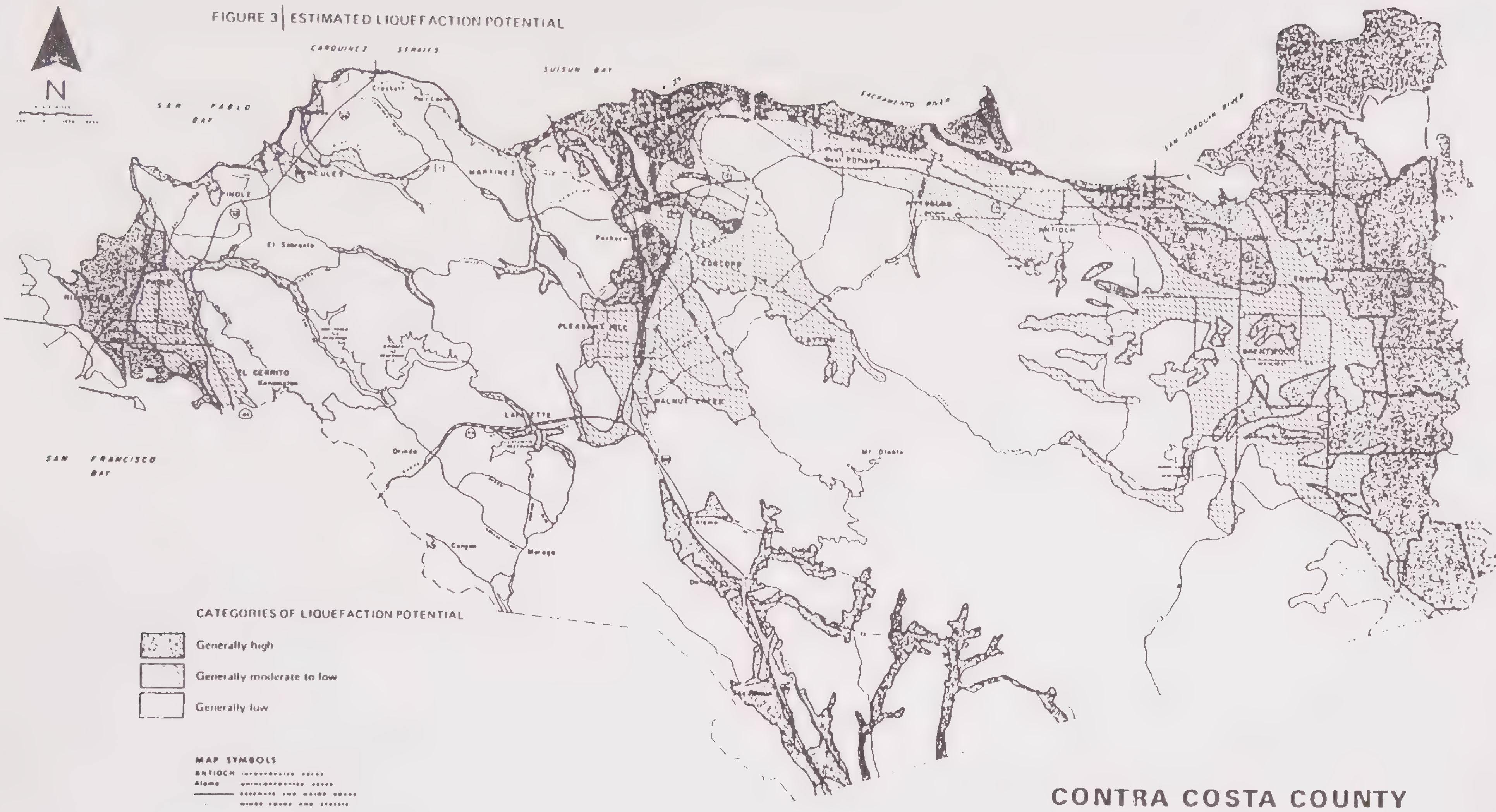
References:
(1) Wesson and Others (1975)
(2) Herd (1979)
(3) Slemmons and Chung (1982)
(4) Earth Science Associates (1982)
(5) Earth Science Associates (1983)
(6) Woodward Clyde Consultants (1984)
(7) Shedlock and Others (1980)
(8) The maximum credible earthquake is the maximum earthquake that appears capable of occurring under the presently known tectonic framework. It is a rational and believable event that is in accord with all known geologic and seismologic facts. In determining the maximum credible earthquake, little regard is given to its probability of occurrence, except that its likelihood of occurring is great enough to be of concern. It is conceivable that the maximum credible earthquake might be approached more frequently in one geologic environment that in another. (CDMG Note 43, 1975).
(9) The maximum probable earthquake is the maximum earthquake that is likely to occur during a 100 year interval. It is to be regarded as a probable occurrence, not as an assured event that will occur at a specific time. (CDMG Note 43, 1975).

Table 11 ESTIMATED MAXIMUM PARAMETERS FOR KNOWN FAULTS AFFECTING CONTRA COSTA COUNTY

Fault	San Andreas	Hayward	Calaveras	Concord	Clayton/Greenville	Antioch
Magnitude[1]	7.0 - 8.25	6.5 - 7.25	6.5 - 7.25	5.75 - 6.5	5.5 - 6.25	5.5 - 6.25
Duration of Strong Shaking [2] (Seconds)	25 - 37	18 - 30	18 - 30	8 - 22	7 - 18	7 - 18
Maximum Intensity [3] (M.M.)	IX - XI	VIII - IX	VIII - IX	VII - VIII	VII - VIII	VII VIII
Peak Horizontal Accelerations on Rock (g)[4]						
Distance from Fault in Miles						
5	.35 - .55	.25 .50	.25 - .50	.15 - .45	.15 - .40	.15 - .40
10	.25 - .45	.15 .40	.15 - .40	.10 - .30	.10 - .25	.10 - .25
20	.15 - .25	.10 - .25	.10 - .25	.05 - .15	.05 - .15	.05 - .15
30	.10 .25	.05 - .20	.05 - .20	.05 - .10	.05 - .10	.05 - .10
40	.05 - .20	.05 - .10	.05 - .10	<.05	<.05	<.05
50	.05 - .15	<.10	<.10	<.05	<.05	<.05

Notes: (1) Magnitude Estimates from Table 1
(2) Bracketed duration for ground motions are 0.05g within 10 miles of the fault. Estimates based on conditions by Bolt (1973).
(3) Estimate based on conditions by Richter (1958)
(4) Estimates based on relationships by Seed and Idriss (1982), Joyner and Boore (1981), Campbell (1981) and Sadigh (1983).

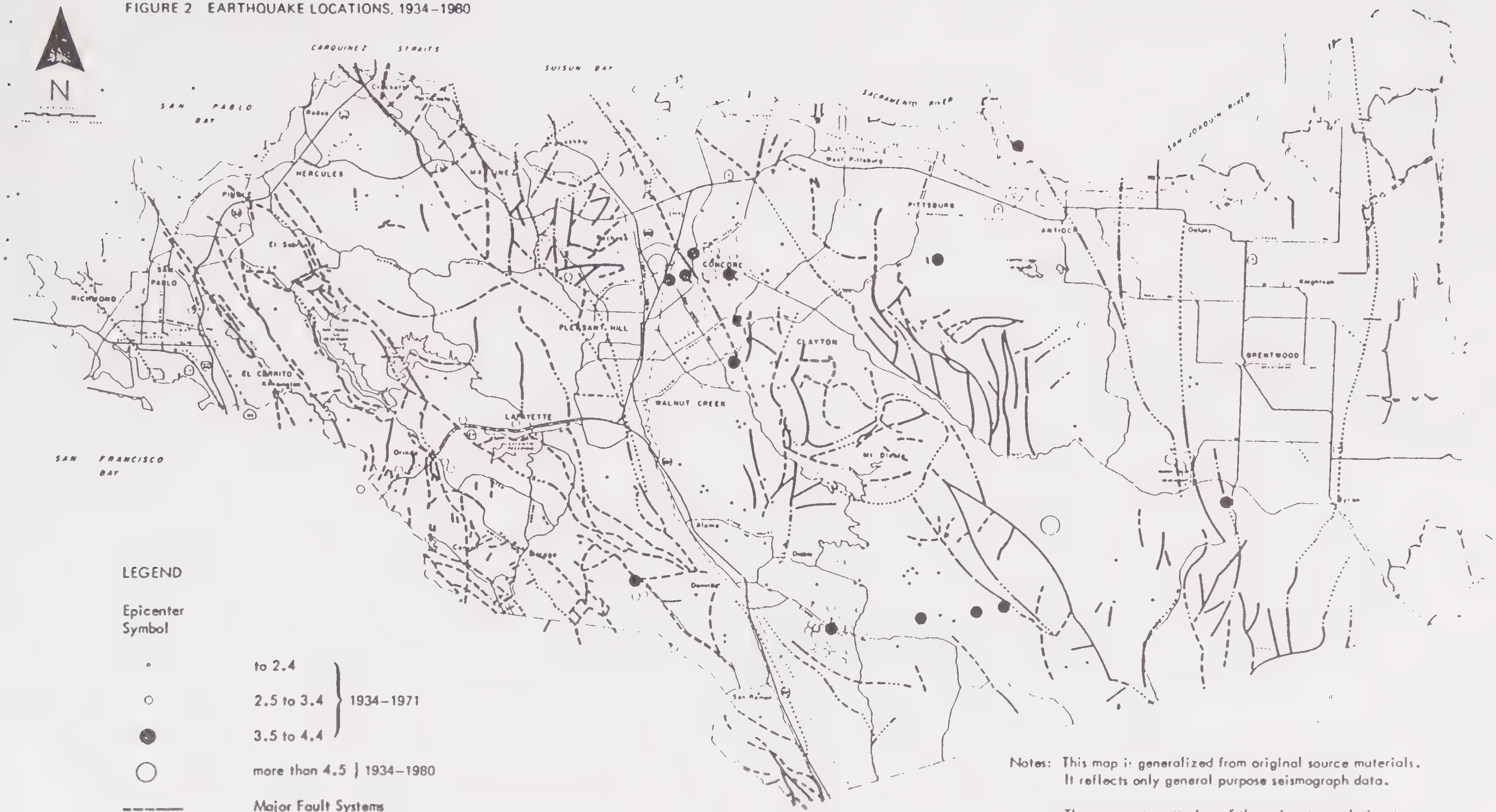
FIGURE 3 | ESTIMATED LIQUEFACTION POTENTIAL



CONTRA COSTA COUNTY
CALIFORNIA

Prepared by the Contra Costa County Community Development Department, Contra Costa County, California.

FIGURE 2 EARTHQUAKE LOCATIONS, 1934–1980



LEGEND

Epicenter Symbol

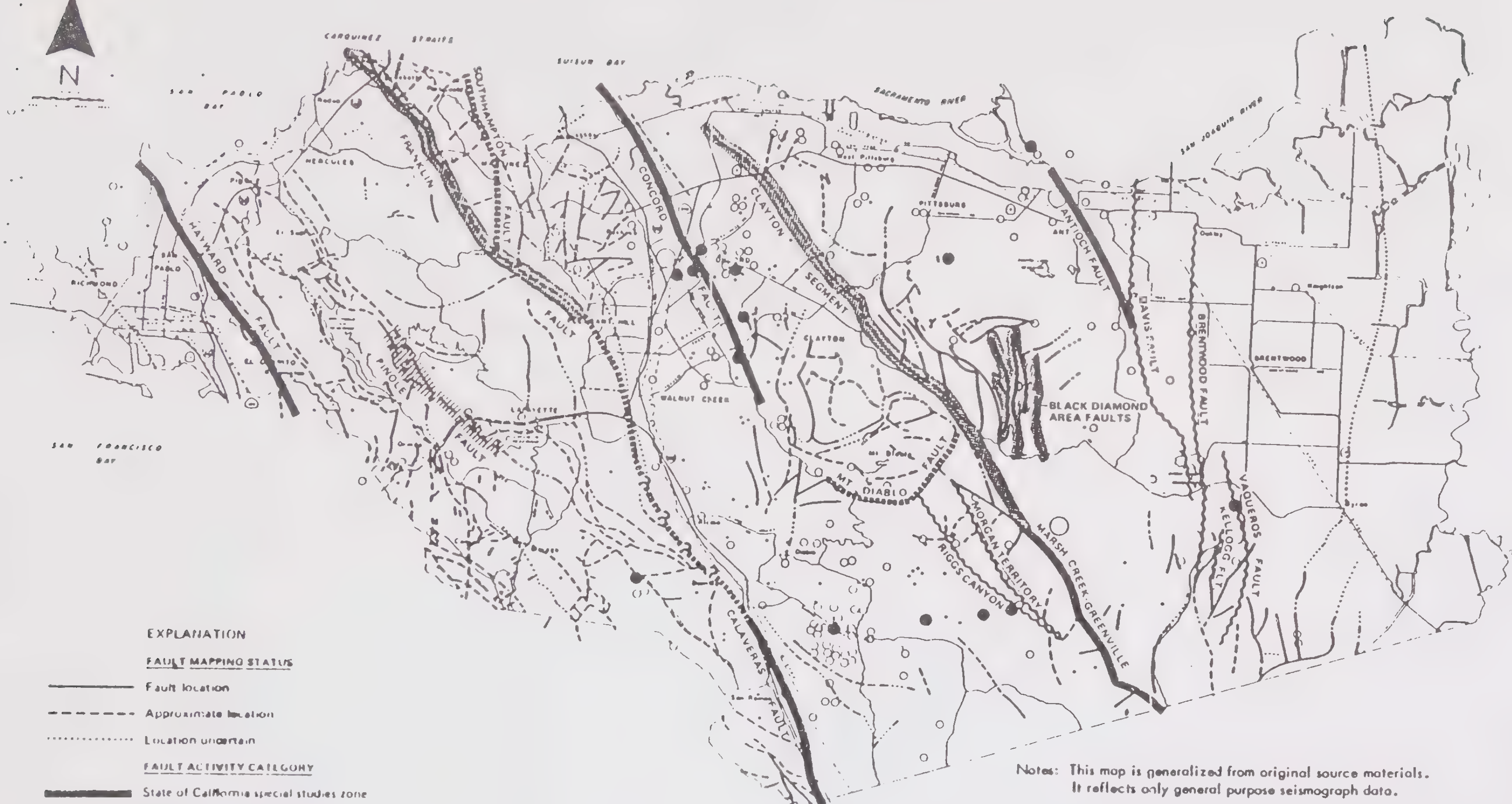
Symbol	Magnitude	Period
•	to 2.4	1934–1971
○	2.5 to 3.4	1934–1971
●	3.5 to 4.4	1934–1971
◯	more than 4.5	1934–1980
-------	Major Fault Systems	

Compiled by the Contra Costa County Community Development Department from the University of California (Berkeley) Seismograph Station Records.

Notes: This map is generalized from original source materials. It reflects only general purpose seismograph data.

The apparent scattering of the epicenters relative to fault locations is due to instrumentation and measurement problems as well as the dip of the faults and other factors.

FIGURE 1 MAPPED FAULTS



EXPLANATION

FAULT MAPPING STATUS

Fault location

Approximate location

Location uncertain

FAULT ACTIVITY CATEGORY

State of California special studies zone

Faults with reported Late Pleistocene displacement but not in a state of California special studies zone

FAULTS WITHOUT EVIDENCE OF LATE PLEISTOCENE OR HOLOCENE SURFACE DISPLACEMENTS

Faults associated with earthquake swarms

Faults inferred active on the basis of scattered small magnitude earthquakes near the trace of the fault

Faults inferred active on the basis of a tectonic model

Notes: This map is generalized from original source materials. It reflects only general purpose seismograph data.

The apparent scattering of the epicenters relative to fault locations is due to instrumentation and measurement problems as well as the dip of the faults and other factors.

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APPENDIX J

FUNDAMENTAL CONCEPTS OF ENVIRONMENTAL NOISE

FUNDAMENTAL CONCEPTS OF ENVIRONMENTAL NOISE

This section provides background information to aid in understanding the technical aspects of this report.

Three dimensions of environmental noise are important in determining subjective response. These are:

a) The intensity or level of the sound;
b) The frequency spectrum of the sound;
c) The time-varying character of the sound.

Airborne sound is a rapid fluctuation of air pressure above and below atmospheric pressure. Sound levels are usually measured and expressed in decibels (dB), with 0 dB corresponding roughly to the threshold of hearing.

The "frequency" of a sound refers to the number of complete pressure fluctuations per second in the sound. The unit of measurement is the cycle per second (cps) or hertz (Hz). Most of the sounds which we hear in the environment do not consist of a single frequency, but of a broad band of frequencies, differing in level. The name of the frequency and level content of a sound is its sound spectrum. A sound spectrum for engineering purposes is typically described in terms of octave bands which separate the audible frequency range (for human beings, from about 20 to 20,000 Hz) into ten segments.

Many rating methods have been devised to permit comparisons of sounds having quite different spectra. Surprisingly, the simplest method correlates with human response practically as well as the more complex methods. This method consists of evaluating all of the frequencies of a sound in accordance with a weighting that progressively de-emphasizes the importance of frequency components below 1000 Hz and above 5000 Hz. This frequency weighting reflects the fact that human hearing is less sensitive at low frequencies and at extreme high frequencies relative to the mid-range.

The weighting system described above is called "A"-weighting, and the level so measured is called the "A-weighted sound level" or "A-weighted noise level." The unit of A-weighted sound level is sometimes abbreviated "dBA." In practice, the sound level is conveniently measured using a sound level meter that includes an electrical filter corresponding to the A-weighting characteristic. All U.S. and international standard sound level meters include such a filter. Typical sound levels found in the environment and in industry are shown in Figure A-1.

Although a single sound level value may adequately describe environmental noise at any instant in time, community noise levels vary continuously. Most environmental noise is a conglomeration of distant noise sources which results in a relatively steady background noise having no identifiable source. These distant sources may include traffic, wind in trees, industrial activities, etc. and are relatively constant from moment to moment. As natural forces change or as human activity follows its daily cycle, the sound level may vary slowly from hour to hour. Superimposed on this slowly varying background is a succession of identifiable noisy events of brief duration. These may include nearby activities such as single vehicle passbys, aircraft flyovers, etc. which cause the environmental noise level to vary from instant to instant.

To describe the time-varying character of environmental noise, statistical noise descriptors were developed. "L_{10}" is the A-weighted sound level equaled or exceeded during 10 percent of a stated time period. The L_{10} is considered a good measure of the maximum sound levels caused by discrete noise events. "L_{50}" is the A-weighted sound level that is equaled or exceeded 50 percent of a stated time period; it represents the median sound level. The "L_{90}" is the A-weighted sound level equaled or exceeded during 90 percent of a stated time period and is used to describe the background noise.

As it is often cumbersome to quantify the noise environment with a set of statistical descriptors, a single number called the average sound level or "L_{eq}" is now widely used. The term "L_{eq}" originated from the concept of a so-called equivalent sound level which contains the same acoustical energy as a varying sound level during the same time period. In simple but accurate technical language, the L_{eq} is the average A-weighted sound level in a stated time period. The L_{eq} is particularly useful in describing the subjective change in an environment where the source of noise remains the same but there is change in the level of activity. Widening roads and/or increasing traffic are examples of this kind of situation.

In determining the daily measure of environmental noise, it is important to account for the different response of people to daytime and nighttime noise. During the nighttime, exterior background noise levels are generally lower than in the daytime; however, most household noise also decreases at night, thus exterior noise intrusions again become noticeable. Further, most people trying to sleep at night are more sensitive to noise.

To account for human sensitivity to nighttime noise levels, a special descriptor was developed. The descriptor is called the DNL (Day/Night Average Sound Level) which represents the 24-hour average sound level with a penalty for noise occurring at night. The DNL computation divides the 24-hour day into two periods: daytime (7:00 am to 10:00 pm) and nighttime (10:00 pm to 7:00 am). The nighttime sound levels are assigned a 10 dB penalty prior to averaging with daytime hourly sound levels. For highway noise environments, the average noise level during the peak hour traffic volume is approximately equal to the DNL.

The effects of noise on people can be listed in three general categories:

a) Subjective effects of annoyance, nuisance, dissatisfaction;
b) Interference with activities such as speech, sleep, and learning;
c) Physiological effects such as startle, hearing loss.

The sound levels associated with environmental noise usually produce effects only in the first two categories. Unfortunately, there has never been a completely predictable measure for the subjective effects of noise nor of the corresponding reactions of annoyance and dissatisfaction. This is primarily because of the wide variation in individual thresholds of annoyance and habituation to noise over time.

Thus, an important factor in assessing a person's subjective reaction is to compare the new noise environment to the existing noise environment. In general, the more a new noise exceeds the existing, the less acceptable the new noise will be judged.

With regard to increases in noise level, knowledge of the following relationships will be helpful in understanding the quantitative sections of this report:

a) Except in carefully controlled laboratory experiments, a change of only 1 dB in sound level cannot be perceived.

b) Outside of the laboratory, a 3 dB change is considered a just-noticeable difference.

c) A change in level of at least 5 dB is required before any noticeable change in community response would be expected.

d) A 10 dB change is subjectively heard as approximately a doubling in loudness, and would almost certainly cause an adverse community response.

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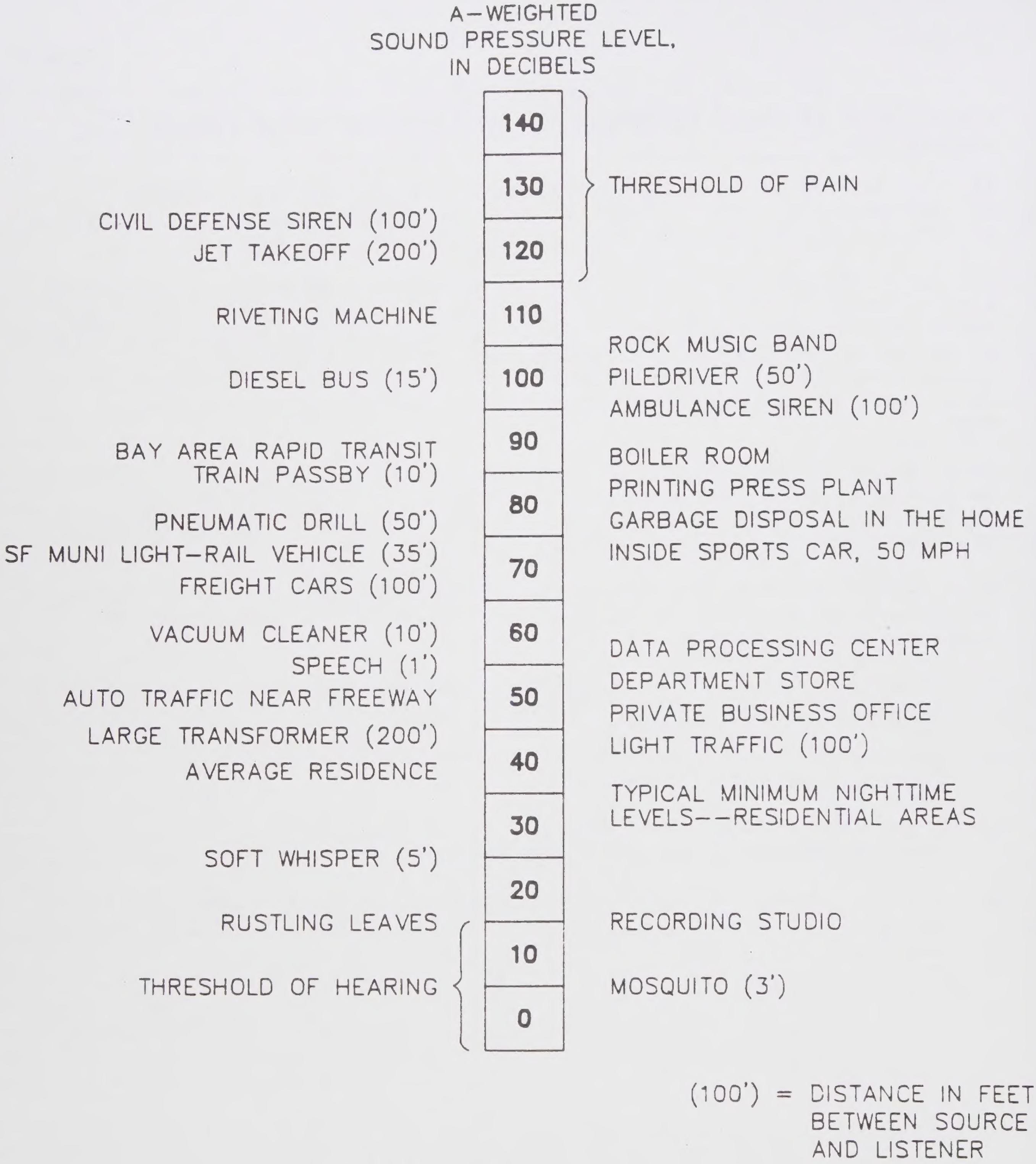

TYPICAL SOUND LEVELS
MEASURED IN THE ENVIRONMENT
AND INDUSTRY

FIGURE A3

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